

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-40 partially

Invention 1

An antisense compound 5 to 50 nucleobases in length targeted to a nucleic acid molecule encoding groEL or groES of a microorganism specifically hybridizing with and inhibiting the expression of groEL or groES, a composition comprising said antisense compound and a pharmaceutically acceptable carrier or diluent, a method of inhibiting the expression of groEL or groES in cells or tissues in vitro comprising contacting said cells or tissues with said antisense compound, an antisense compound up to 50 nucleobases in length targeted to a nucleic acid molecule encoding groEL or groES comprising at least a 5 nucleobase portion of SEQ ID NO: 16, a composition comprising said antisense compound and a pharmaceutically acceptable carrier or diluent, a method of inhibiting the expression of groEL or groES in cells or tissues in vitro comprising contacting said cells or tissues with said antisense compound, an antisense oligonucleotide comprising 5 to 50 nucleotides which are complementary to the groEL or groES gene of a microorganism, a pharmaceutical composition comprising a pharmaceutically acceptable excipient and an effective amount of said antisense oligonucleotide, a method of inhibiting the expression of a groEL or groES gene in a microorganism comprising administering to said microorganism or to a cell infected with said microorganism an effective amount of said antisense oligonucleotide, an antisense oligonucleotide comprising 5 to 50 nucleotides being capable of binding to the groEL or groES gene of a microorganism and comprising all or part of the sequence SEQ ID NO: 16, a pharmaceutical composition comprising a pharmaceutically acceptable excipient and an effective amount of said antisense oligonucleotide, a method of inhibiting the growth of a microorganism comprising identifying said microorganism and administering to said microorganism an effective amount of an antisense oligonucleotide comprising at least 5 nucleotides being complementary to either the groEL or groES gene of said microorganism;

2. Claims: 1-40 partially

Invention 2

Idem as subject 1 but limited to SEQ ID NO: 17;

3.-465. Claims: 1-40 partially

Inventions 3-465

Idem as subject 1 but limited to SEQ ID NOS: 18-480

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

(corresponding to Tabs. 1-4 of the description).

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA 00/01347

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Although claim 40 is directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-40 partially

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| (51) International Patent Classification⁶ : C07H 21/00, A61K 31/70, C12N 15/11 | A1 | (11) International Publication Number: WO 98/03533 (43) International Publication Date: 29 January 1998 (29.01.98) |
| (21) International Application Number: PCT/US97/12961 (22) International Filing Date: 23 July 1997 (23.07.97) (30) Priority Data: 08/685,575 24 July 1996 (24.07.96) US (71) Applicant: OLIGOS ETC. AND OLIGOS THERAPEUTICS, INC. [US/US]; 29970 S.W. Town Center Loop W., Wilsonville, OR 97070 (US). (72) Inventors: ARROW, Amy; 15 Equestrian Ridge Road, Newton, CT 06470 (US). DALE, Roderic, M., K.; 26761 S.W. 45th Drive, Wilsonville, OR 97070 (US). THOMPSON, Theresa, L.; 2222 S.W. Ek Road, West Linn, OR 97068 (US). (74) Agents: FRIEBEL, Thomas, E. et al.; Pennie & Edmonds LLP, 1155 Avenue of the Americas, New York, NY 10036 (US). | | (81) Designated States: AL, AM, AU, AZ, BA, BB, BG, BR, BY, CA, CN, CU, CZ, EE, GE, GH, HU, IL, IS, JP, KG, KP, KR, KZ, LC, LK, LR, LT, LV, MD, MG, MK, MN, MX, NO, NZ, PL, RO, RU, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |
| (54) Title: ANTISENSE OLIGONUCLEOTIDES AS ANTIBACTERIAL AGENTS | | |
| (57) Abstract A novel method is provided that teaches the therapeutic use of nuclease resistant oligonucleotides for treating animals having an infection caused by a pathogenic bacterium. The method involves the integration of (1) methods for selecting the correct oligonucleotide, (2) synthesis and purification of nuclease resistant oligonucleotides, and (3) methods for <i>in vitro</i> analysis of potential antimicrobial oligonucleotides. The described oligonucleotides may comprise modified backbones, sugar residues, bases, or mixtures and have been subject to purification resulting in oligonucleotides that are capable of inhibiting the growth of a broad spectrum of clinically relevant bacterial species. | | |

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ANTISENSE OLIGONUCLEOTIDES AS ANTIBACTERIAL AGENTS

The present application claims priority to United States Patent Application Serial No. 08/685,575, filed July 24, 1996.

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FIELD OF THE INVENTION

The present invention is directed to methods for treating an animal, including a human, having a bacterial infection which comprise administering an oligonucleotide specifically targeted to, or otherwise capable of interacting with, a bacterial sequence, or nucleic acid binding protein. The antibacterial oligonucleotide inhibits the growth of the bacteria, blocks the expression of virulence factors or genes involved in the transfer of genetic information, or kills the bacteria. Alternatively, the oligonucleotide may also be targeted to an antibiotic resistance gene in order to render the bacteria sensitive to an otherwise ineffective antibiotic. The invention also relates to nuclease resistant oligonucleotides that are effective in inhibiting the growth of, or killing, pathogenic bacteria.

1.0. BACKGROUND TO THE INVENTION1.1. Antibiotic Prior Art

Pathogenic bacteria responsible for infectious diseases were once thought to be totally under control through the use of a battery of antibiotics such as penicillin, streptomycin, tetracycline, and others. However, since the widespread use of antibiotics began in the 1950s, more and more bacteria resistant to one or more antibiotics have arisen. Multiple drug resistant strains are increasingly common, particularly in hospitals.

Currently, nosocomial Staphylococcal infections exhibit multiple drug resistance. See, for example, Archer et al., Antimicrob. Agents Chemother. 38:2231-2237 (1994). At this time, the remaining antibiotic that demonstrates the ability to kill *Staphylococci* is vancomycin. Strains of *Enterococci* that are vancomycin resistant have already been isolated and

reported by Zabransky et al., J. Clin. Microbiol. 33(4):791-793 (1995). Furthermore, transfer of resistance from *Enterococci* to *Staphylococci* has been previously documented by Woodford et al., J. Antimicrob. Chemother. 35:179-184 (1995). *Streptococcus pneumoniae* is a leading cause of morbidity and mortality in the United States (M.M.W.R., Feb. 16, 1996, Vol. 45, No. RR-1). Each year these bacteria cause 3,000 cases of meningitis, 50,000 cases of bacteremia, 500,000 cases of pneumonia, and 7,000,000 cases of otitis media. Case fatality rates are greater than 40% for bacteremia and greater than 55% for meningitis, despite antibiotic therapy. In the past, *Streptococcus pneumoniae* were uniformly susceptible to antibiotics; however, antibiotic resistant strains have emerged and are becoming widespread in some communities.

In addition, there are instances where antibiotic resistance is not an issue, yet a particular bacteria remains refractory to treatment using conventional antibiotics. Such is the case with *Escherichia coli* 0157:H7, the causative agent for food poisoning and death from undercooked meat. The Department of Agriculture estimates that 10 people die each day and another 14,000 become ill due to this bacteria. Unfortunately, conventional antibiotics are completely ineffective against this organism.

The history of antibiotic treatment of pathogenic bacteria is cyclical. Bacteria are remarkably adaptive organisms, and, for each new antibiotic that has been developed, resistant bacterial strains arise through the widespread use of the antibiotic. Thus, there is a constant need to produce new antibiotics to combat the next generation of antibiotic resistant bacteria. Traditional methods of developing new antibiotics have slowed, and in the past two years only one new antibiotic has been approved by the FDA. Furthermore, according to Kristinsson (Microb. Drug Resistance 1(2):121 (1995)), "There are no new antimicrobial classes with activity against resistant Gram positives on the horizon."

1.2. Antisense Nucleotide Art

Antisense polynucleotides are useful for specifically inhibiting unwanted gene expression in mammalian cells. They can be used to hybridize to and inhibit the function of an RNA, typically a messenger RNA, by activating RNase H or physically blocking the binding of ribosomes or proteins, thus preventing translation of the mRNA. Antisense oligonucleotides also include RNAs with catalytic activity (ribozymes), which can selectively bind to complementary sequences on a target RNA and physically destroy the target by mediating a cleavage reaction.

Antisense oligonucleotides that bind to the DNA at the correct location can also prevent the DNA from being transcribed into RNA. These antigene oligonucleotides are believed to bind to double-stranded DNA (forming triple-stranded DNA) and thereby inhibit gene expression.

1.3. Antisense Nucleotides For Therapy

The use of antisense oligonucleotides has emerged as a powerful new approach for the treatment of certain diseases. However, the preponderance of the work to date has focused on the use of antisense oligonucleotides as antiviral agents or as anticancer agents (Wickstrom, E., Ed., Prospects for Antisense Nucleic Acid Therapy of Cancer and AIDS, New York: Wiley-Liss, 1991; Crooke, S.T. and Lebleu, B., Eds., Antisense Research and Applications, Boca Raton: CRC Press, 1993, pp. 154-182; Baserga, R. and Denhardt, D.T., 1992, Antisense Strategies, New York: The New York Academy of Sciences, Vol. 660; Murray, J.A.H., Ed., Antisense RNA and DNA, New York: Wiley-Liss, 1993).

There have been numerous disclosures of the use of antisense oligonucleotides as antiviral agents. For example, Agrawal et al. report phosphoramidate and phosphorothioate oligonucleotides as antisense inhibitors of HIV (Agrawal et al., Proc. Natl. Acad. Sci. USA 85:7079-7083 (1988)). Zamecnik et al. disclose antisense oligonucleotides as inhibitors of Rous sarcoma virus replication in chicken

fibroblasts (Zamecnik et al., Proc. Natl. Acad. Sci. USA 83:4143-4146 (1986)).

There seem to be few to no toxicity problems associated with the use of antisense oligonucleotides as drugs to treat disease. To date, no dose limiting toxicities of phosphorothioate antisense oligonucleotides have been detected in man (Crooke, S.T., "Progress in Oligonucleotide Therapeutics," Abstracts American Association for Cancer Research, March 18-22, 1995; Crooke, S.T., "Progress in Oligonucleotide Therapeutics," Abstracts Oligonucleotide-Based Therapeutics, February 9-10, 1995), and phosphorothioate oligonucleotides have been found to have no effect on developing embryos (Guadette et al., Antisense Res. Devel. 3:391-397 (1993)). In fact, under an emergency IND approval, a 19-year-old male received 700 mg of an antisense phosphorothioate oligonucleotide to treat acute myeloblastic leukemia (Bayever et al., Antisense Res. Devel. 2:109-110 (1992)). There were no changes in pulse, respiratory rate, blood pressure, fever, mucositis, or diarrhea in the patient. In addition; no neurological, cardiovascular, respiratory, renal, skin or nephrourological toxicities were observed. It was concluded that systemic administration of a phosphorothioate antisense oligonucleotide to humans achieves adequate bioavailability of the drug to target tissues without major toxicity. In a follow up study, the antisense phosphorothioate oligonucleotides were given to five patients with acute myeloblastic leukemia. After systemic intravenous administration of the oligonucleotide, no toxic effects were seen. See Fig. 1 of Bayever et al., Antisense Res. Devel. 3:383-390 (1993). The authors concluded that the favorable pharmacokinetics observed support the use of phosphorothioate oligonucleotides as potential gene specific therapeutic agents.

1.4. The Transport Problem For Oligonucleotides

While the use of antisense oligonucleotides as antiviral agents has been described (Agrawal et al., Pat. No. 5,194,428, issued March 16, 1993), no significant progress has been made in the therapeutic use of antisense oligonucleotides to treat bacterial infection. In fact, at a recent meeting on Antibiotic Discovery addressing the current state of the art, there were no talks or discussions scheduled regarding the use of antisense oligonucleotides to treat bacterial infections, although the use of antisense oligonucleotides as antiviral agents was scheduled for discussion ("Antibiotic Discovery," Abstracts International Business Communications, June 26-27, 1995).

Logically, the use of synthetic oligonucleotides should be advantageous as an approach to treating bacterial infection because sequences can be specifically designed to inhibit bacterial growth while not interfering with the metabolism of mammalian cells.

In addition, oligonucleotides have been shown to nonspecifically stimulate the immune system (Yamamoto et al., Antisense Res. Devel. 4:119-122 (1994); Krieg et al., Nature 374:546-549 (1995)). Since current antibiotics generally function by arresting bacterial growth until the immune system can respond to the infection (Myrvik, Fundamentals of Medical Bacteriology, 1974, Lea & Febiger, Publishers), the use of oligonucleotides as antibiotics may provide both a nonspecific stimulation of the immune system as well as the relatively specific inhibition of the growth of a particular bacteria.

Furthermore, infectious bacteria have been shown to become sequestered in the liver and spleen in clinical infections (Wilson, G.S. and Miles, A.A., Eds., Topley and Wilson's Principles of Bacteriology and Immunology, Williams & Wilkins, Publishers, 1964). Oligonucleotides, or more specifically S-oligonucleotides (phosphorothioate substituted), have also been shown to accumulate in these organs (Agrawal et al., Proc. Natl. Acad. Sci. USA 88:7595-

7599 (1991)). Therefore, the use of antisense oligonucleotides should be ideally suited to the treatment of bacterial infections involving the liver and spleen as well as systemic bacteremia and septicemia.

5 The rigid cellular architecture of the prokaryote has been viewed as a barrier to oligonucleotide uptake by bacterial cells (Chrissey et al., *Antisense Res. Devel.* 3:367-381 (1993)). In fact, reports of antisense oligonucleotide-mediated gene inhibition in bacteria have attempted to
10 circumvent the perceived problem of the rigid cell wall by conducting experiments in cell-wall deficient strains (Jayaraman et al., *Proc. Natl. Acad. Sci. USA* 78:1537-1541 (1981)), in competent bacterial cells (Ciferri et al., *J. Bacteriol.* 104:684-688 (1970)), in heat-shock permeabilized
15 bacteria (Gasparro et al., *Antisense Res. Devel.* 1:117-140 (1991)), in hypertonic solutions (Chrissey et al., *Antisense Res. Devel.* 3:367-381 (1993)), and using PEG-modified oligonucleotides (Rahman et al., *Antisense Res. Devel.* 1:319-327 (1991)), none of which has relevance to treating clinical
20 bacterial infections.

Lupski et al., Pat. No. 5,294,533 ('533 patent), stated that antisense oligonucleotides can preferentially inhibit the growth of Gram negative and Gram positive bacteria in a mixed culture of Gram negative and Gram positive bacteria.
25 Lupski et al. also taught that end-capped oligonucleotides should be used (see column 4, lines 39-42), but since end-capping does not provide protection from intracellular endonucleases (see the discussion of Hoke et al. above), one skilled in the art would not expect the method of Lupski et
30 al. to work. Thus, the '533 patent does not provide an enabling description of the use of antisense oligonucleotides to inhibit the growth of bacteria in vivo in mammals.

Moreover, the '533 patent did not disclose the genotype of the bacteria used in the study. Thus, there is no way to
35 establish whether clinical isolates were used or permeability enhanced bacterial mutants were used. Additionally, the '533 patent does not provide adequate teaching to allow one to

discern whether or not the described bacteria had been previously rendered competent by established prior art methods. In view of this lack of disclosure, the '533 patent does not teach methods that are broadly applicable to 5 clinically significant bacterial infections in mammals.

The prior art teaches the inherent difficulty of successfully using oligonucleotides to inhibit the growth of intact bacteria (Jayaraman et al. and Ciferri et al.), and the '533 patent does not provide sufficient disclosure to 10 refute the clear teaching in the prior art. Instead, the '533 patent simply states that: "A small 10-29 mer antisense oligonucleotide that is delivered to a bacteria is rapidly transported into the bacterial cells." This statement is clearly contrary to what is taught by the prior art.

15 The prior art has never conclusively established that the growth of wild type bacteria may be inhibited by either nuclease resistant or nuclease sensitive oligonucleotides. It was also well known that methylcarbamate modified oligonucleotides (the methylcarbamate replaced the 20 phosphodiester bonds) of three and four nucleotide units, and methylphosphonates longer than four nucleotide units could not enter *Escherichia coli* cells (Jayaraman et al., Proc. Natl. Acad. Sci. USA 78:1537-1541 (1981), Rahman et al., Antisense Res. Devel. 1:319-327 (1991)). Thus, the prior art 25 teaches that the alleged results described in the '533 patent conflict with previously reported results from bacterial experiments using nuclease resistant oligonucleotides, or phosphodiester oligonucleotides.

In 1993, Chrisey reported uptake *in vitro* of 30 phosphorothioate oligonucleotides into *Vibrio* bacteria under hypertonic conditions, and were only able to show uptake when the cells were grown under conditions that enhanced the permeability of the bacterial cells (i.e., in a hypertonic minimal medium). From these data, Chrisey et al. concluded 35 that, in enriched media (blood, serum, and other extracellular fluids), oligonucleotides may not be preferred antibacterial agents for use *in vivo*.

1.5. Oligonucleotides As Antibacterial Agents

As discussed above, essentially five publications have addressed the possibility of using oligonucleotides to inhibit bacterial growth. Four out of five of these 5 publications (Rahman, Chrisey, Jayaraman, and Gasparro) teach that oligonucleotides are not able to inhibit the growth of unmodified (intact) bacteria. Additionally, the last reference (Lupski) provides no teaching of how to inhibit the growth of intact bacteria, and provides no illustrative 10 examples that such inhibition is indeed possible.

Taken as a whole, the above publications would have not provided a reasonable expectation that one could in fact use oligonucleotides to inhibit the growth of intact bacteria. The inadequacies of the background art may be explained by 15 the fact that the present applicants have discovered that at least several features of the design, preparation, and use of oligonucleotides may affect antibacterial efficacy. These features include, but are not limited to: 1) the dose of oligonucleotide; 2) the length of the oligonucleotide; 3) the 20 growth conditions used during the *in vitro* assay; 4) the chemical backbone of the oligonucleotide; and 5) the method of post-synthesis purification. Each of these features are discussed in greater detail below.

The dose of oligonucleotide may significantly effect the 25 observed amount of growth inhibition. Fig. 1 shows that the percent of inhibition varies from 100% down to about 19% as the dose of oligonucleotide is reduced from 285 μ M to 5 μ M in a standard MIC assay (described in Section 4.5, *infra*). Of the background references, only Rahman and Jayaraman taught 30 concentrations of oligonucleotide that fall within the disclosed range (but observed little to no inhibitory effect against intact bacteria).

The applicants have also found that the length of the oligonucleotide is directly related to its ability to 35 specifically bind and inhibit the normal function of the target sequence. Shorter oligonucleotide sequences generally have a reduced T_m (duplex melting temperature) and are thus

more likely to cause undesirable side effects of nonspecific binding or have no effect. Gao et al., *Molec. Pharm.* 41:223-229 (1992) have shown that, using an *in vitro* enzymatic assay, the inhibitory effect of an oligonucleotide sequence increased as the length of the oligonucleotide was progressively increased from a 7mer up to a 28mer. Gao et al. observed no specific inhibitory activity when a 7mer was tested. Of the cited references, Rahman, Jayaraman, Gasparro, and Chrisey used oligonucleotides that were a maximum of only 12 bases in length. Typically, oligonucleotides as short as the disclosed 12mers show a high degree of nonspecific binding. Lupski chose sequences of about 25 bases in length but the majority of the disclosed sequences comprised a high degree of degeneracy which allows for binding to multiple target sites. For example, oligonucleotides comprising bases such as inosine, or "N" (which indicates the use of A, C, G, or T), are usually produced when one wishes to allow binding to sequences where the precise target sequence is unknown (Ohtsuka et al., *J. Biol. Chem.* 260:2605 (1985)). Sequences with such broad based homology run the risk of nonspecific binding to host sequences and associated toxicity effects. Additionally, Lupski's teaching is inherently suspect given that no data demonstrating the inhibition of bacterial growth was provided.

It should also be noted that shorter oligonucleotide sequences generally have reduced Tm's. The oligonucleotides taught by Rahman, Jayaraman, Gasparro, and Chrisey were generally so short that the Tm's for the oligonucleotide-target sequence hybrids were usually below 37° C. For example, the 12mer phosphorothioate sequence taught by Chrisey has a predicted Tm of 28.9° C, the 9mer taught by Gasparro had a predicted Tm of 24.7° C, and the 7mer (AGGAGGT) taught by Jayaraman and 4mer (GGAG) taught by Rahman both had a predicted Tm's well below 10° C. Given these data, it is clear that oligonucleotides of the length

taught by these references are generally not useful as antisense or antigene agents under physiologic conditions.

The growth rate and conditions under which antibiotic susceptibility are measured may profoundly effect a bacterium's sensitivity to antibacterial agents (Arrow et al., Antimicrob. Agents Chemother. 26:507 (1984)), and the uptake of the antibiotic into the cell (Arrow et al., Microbiol. Rev. 51:439-457 (1987)). Accordingly, methods for screening oligonucleotides *in vitro* for antibacterial activity should generally be conducted under standardized conditions that reflect the *in vivo* circumstances of a given pathogen such as the NCCLS MIC tests (see Section 4.5, *infra*). None of the background references recognized that growth conditions might effect the result of antibiotic susceptibility tests, and thus none of these references assayed for the inhibition of bacterial growth using the standardized growth conditions defined in the MIC tests.

Among other things, the antibacterial efficacy of an oligonucleotide may be directly related to the relative nuclease resistance of the chemical backbone of the oligonucleotide. Gasparro and Lupski did not recognize this facet of the present invention and thus did not teach oligonucleotides that were designed to be nuclease resistant. Consequently, the oligonucleotides used by Gasparro and Lupski would have been rapidly degraded by the cell (see Section 1.6, *infra*), and would thus have little utility as antibacterial agents.

Additionally, the post-synthesis handling and purification of the oligonucleotides may profoundly effect antibacterial efficacy. None of the background references recognized the particular importance of post-synthesis handling, and thus none of the references explicitly suggest or describe purification protocols that produce effective antibacterial oligonucleotides.

In summary, none of the background references recognized the importance of the features described above. In brief, Rahman and Jayaraman both failed to provide explicit teaching

of oligonucleotides of the correct length, the use of proper susceptibility assays, or the correct purification scheme; Gasparro failed to explicitly teach the correct dose of oligonucleotide, oligonucleotides of the correct length, the use of proper susceptibility assays, the importance of nuclease resistant backbones, or the correct purification scheme; Chrisey failed to explicitly teach the correct dose of oligonucleotide, oligonucleotides of the correct length, the use of proper susceptibility assays, or the correct purification scheme; and Lupski failed to explicitly teach the correct dose of oligonucleotide, the use of proper susceptibility assays, the importance of nuclease resistant backbones, or the use of purified oligonucleotides. The background references, considered as a whole, failed to recognize the importance of all of the features described above. Furthermore, none of the background references used intact clinical isolates for their studies. Accordingly, the use of oligonucleotides to inhibit the growth of clinically relevant (i.e., intact) strains of bacteria remained elusive. Conversely, the present disclosure teaches the importance of all of the above features, and integrates all of them to provide the first teaching of the use of antibacterial oligonucleotides to inhibit the growth of clinically relevant bacterial pathogens.

25

1.6. Nuclease Resistant Oligonucleotides

It has been demonstrated that the fate of internalized oligonucleotides is critical to the success of antisense gene therapy (Bennett, Antisense Res. Devel. 3:235-241 (1993)). The rapid intracellular degradation of oligonucleotides is a barrier to efficient inhibition of gene expression. One of the major problems in utilizing naturally occurring phosphodiester oligonucleotides is their rapid degradation by nucleases in mammalian cells or in serum-containing culture medium (Cohen, Oligodeoxynucleotides: Antisense Inhibitors of Gene Expression, Boca Raton, Fla., CRC Press (1989)).

There is abundant evidence that modification of the backbone

of oligonucleotides confers varying degrees of nuclease resistance. Hoke et al., Nucl. Acids Res. 19:5743 (1991) compared phosphodiester backbone oligonucleotides to fully modified phosphorothioate backbone oligonucleotides, and to
5 chimeric phosphodiester and phosphorothioate backbone oligonucleotides. Hoke et al. demonstrated that the phosphorothioate oligonucleotides were degraded up to 45 times slower than the phosphodiester or chimeric backbone oligonucleotides.

10 There have been reports that chimeric oligonucleotides that are end-capped with nuclease resistant backbone linkages are resistant to degradation (Cohen, "Oligodeoxynucleotides: Antisense Inhibitors of Gene Expression," Boca Raton, Fla., CRC Press (1989)). However, Hoke et al. teach that capped
15 oligonucleotides are rapidly degraded by intracellular endonucleases, and thus, that capping oligonucleotides with nuclease resistant modifications may not be sufficient for sustaining pharmacological activities of oligonucleotides in cells. Finally, Hoke et al. concludes that while capping of
20 oligonucleotides may provide protection from exonucleases in cell culture, the action of intracellular endonucleases is sufficient to degrade these capped oligonucleotides when they enter a cell.

Hoke et al. is corroborated by Gao et al. who studied
25 the relationship between the structure of the phosphodiester/phosphorothioate chimeras and nuclease resistance. Gao et al. showed a correlation between the number of phosphorothioate linkages and nuclease resistance of the oligonucleotide.

30 Extending these concepts, Zhao et al., Antisense Res. Devel. 3:53-66 (1993), have looked at the effects of backbone modifications on cellular uptake of oligonucleotides in eukaryotes. This is an important property as the efficacy of an antisense oligonucleotide will be influenced by cellular
35 uptake. Zhao et al. demonstrated that cell surface binding and uptake was greatest for phosphorothioate oligonucleotides followed by phosphodiester/phosphorothioate chimeras, and

finally by phosphodiester backbone oligonucleotides. Chrisey et al., Antisense Res. Devel. 3:367-381 (1993), looked at the uptake and stability of phosphodiester and phosphorothioate backbone oligonucleotides by bacteria under hypertonic
5 conditions. Chrisey et al. concluded that phosphorothioate 6mers were relatively resistant to nuclease activity in *Vibrio parahaemolyticus* cells and were relatively non-toxic. However, Chrisey et al. did not demonstrate that the internalized 6mers had antimicrobial activity.

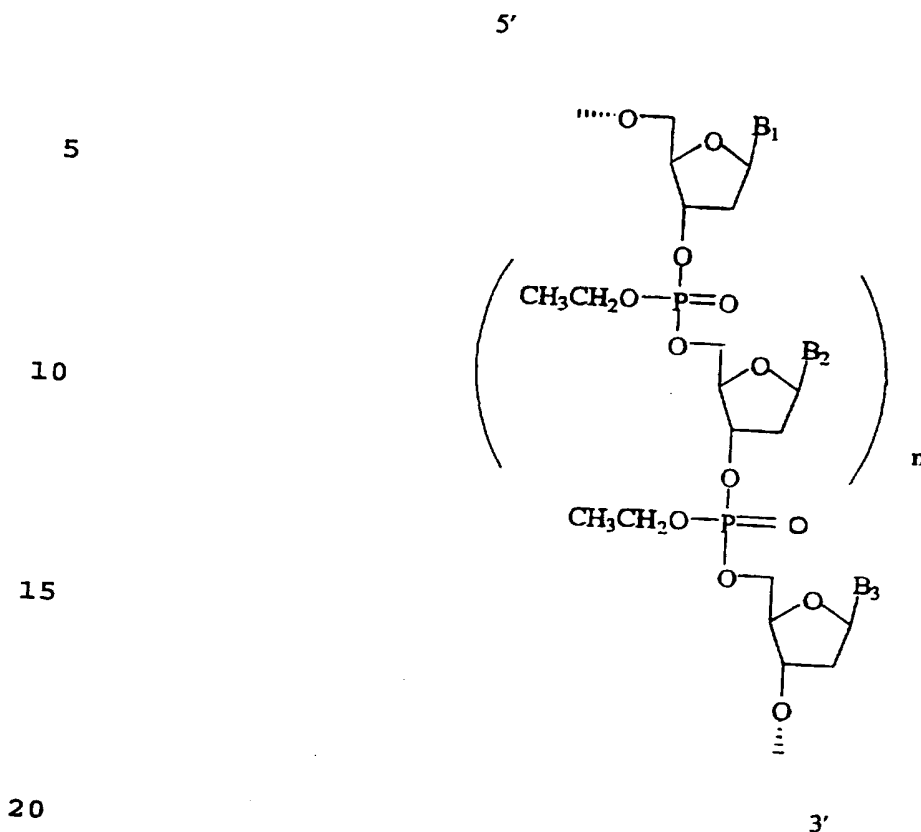
10 Various modifications to the oligonucleotide backbone have been found to inhibit nuclease degradation. Such nuclease resistant modified nucleotides are well described in the literature and include, but are not limited to, the methylphosphonates, p-ethoxy deoxyribonucleotides, p-ethoxy
15 2'-O-methyl ribonucleotides, 2'-O-methyl ribonucleotides, phosphorothioates, and others. A brief description of representative nuclease resistant oligonucleotide backbones follows:

Methylphosphonate oligonucleotides, in addition to
20 exhibiting enhanced nuclease resistance, also have increased hydrophobicity over phosphodiester oligonucleotides and therefore have greater permeability to cell membranes as compared to phosphodiester or other more highly charged oligonucleotides.

25 p-Ethoxy deoxyribonucleotides have an ethyl group o-linked to the phosphate backbone. p-Ethoxy deoxyribonucleotides are resistant to nuclease degradation. p-Ethoxy ribonucleotides have the following structure:

30

35

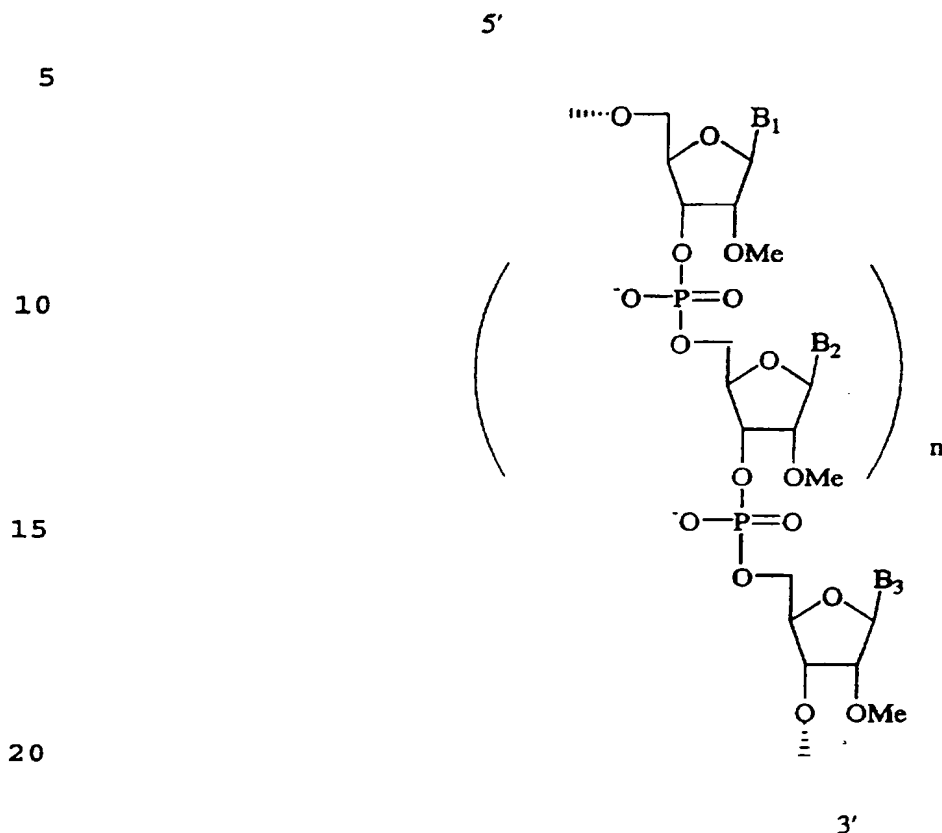


Phosphorothioates are compounds in which one of the non-bridging oxygen atoms in the phosphate backbone of the nucleotide is replaced by a sulfur atom. The phosphorothioates are resistant to cleavage by nucleases and, since they have the same number of charged groups as phosphodiester oligonucleotides, have good solubility in water. These compounds also exhibit more efficient hybridization with complementary DNA sequences than the corresponding methylphosphonate analogues.

Methyl carbonates are compounds in which one of the nonbridging oxygen atoms in the phosphate backbone has been replaced by a methyl carbonate group.

2'-O-methyl ribonucleotides are compounds in which the 2' position of the ribose sugar ring has a methoxy group in

place of the normal hydroxyl group. 2'-O-methyl ribonucleotides have the following general structure:



Secondary structure can also be used to make
 25 oligonucleotides resistant to nucleases. Oligonucleotides
 with a hairpin loop structure extending from the 3'-terminus,
 stabilizing the oligonucleotide against 3'-nucleolytic
 degradation, have been reported by Khan and Coulson, Nucl.
 Acids Res. 21(12):2957-2958 (1993). The T_m of the modified
 30 oligonucleotide from its complementary mRNA target was
 unaffected by the presence of the loop modification.

Further, end modification of oligonucleotides can also
 render an oligonucleotide resistant to nucleases, such as,
 for example, attaching cholesterol, psoralen, rhodamine,
 35 fluorescein, DNP, amine groups, biotin, inverted (3'-3' or
 5'-5') linkages, and the like, to the end of the
 oligonucleotide in order to render it more nuclease resistant.

2.0. SUMMARY OF THE INVENTION

The present invention relates to methods for the treatment of animals, including humans, that have a bacterial disease. The preferred method of treatment comprises the administration of a purified antibacterial oligonucleotide having about 8 to about 80 nucleotides to the animal in an amount sufficient to inhibit bacterial growth, alleviate a symptom of the infection, or in an amount effective for treatment.

10 The purified antibacterial oligonucleotides of the present invention will preferably bear an enhanced ability to inhibit the growth of bacterial cells relative to previously disclosed oligonucleotide preparations. The present invention also represents the first disclosure of the use of
15 oligonucleotides to inhibit the growth of intact clinically relevant bacteria. The oligonucleotides generally inhibit bacterial growth by acting as antisense or antigene inhibitors of bacterial gene expression (when targeted to bacterial nucleic acid sequences), or by acting aptamerically
20 to alter the function of specific bacterial proteins or polypeptides (when associating target amino acid sequences contained in bacterial peptides, polypeptides, and proteins). Alternatively, the oligonucleotides are targeted to an antibiotic resistance gene to render the bacteria sensitive
25 to a conventional antibiotic. In preferred embodiments, the antibacterial oligonucleotides are substantially nuclease resistant (i.e., resistant to nuclease activity).

Additional embodiments of the present invention are antibacterial oligonucleotides that have been produced by a
30 process that enhances the oligonucleotide's antibacterial activity. In particular, the presently described antibacterial oligonucleotides will be produced, or otherwise purified, by a process comprising either individually or in combination ion exchange or reverse phase chromatography,
35 extractions, precipitations, gel filtrations, dialysis, diafiltration or functional equivalents. Column chromatography may be by traditional of methods or High-

Performance Liquid Chromatography (HPLC), fast performance liquid chromatography (FPLC), and the like. Additionally, the oligonucleotides may be purified by processes including, for example, extraction or precipitation with alcohols or 5 organic solvents.

The present invention further contemplates the use of the described antibacterial oligonucleotides, in conjunction with an acceptable pharmaceutical carrier, to prepare medicinal compositions for the treatment of bacterial 10 infections in animals, and more preferably mammals, including humans.

3.0. BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a dose response curve of different 15 concentrations of antibacterial oligonucleotide NBT 89 (SEQ ID NO. 61) when tested against *Escherichia coli* ATCC accession No. 25922.

Figure 2 provides a nonexhaustive graph of the types of bacterial genes which proved susceptible to inhibition by 20 antibacterial oligonucleotides. The ordinate shows the categories of bacterial genes defined in Table 2(A-W).

Figures 3(a-c) show the percent inhibition of the growth of the indicated target bacteria after addition of the indicated oligonucleotide as a function of time.

25 Figures 4(a-c) show the percent inhibition of the growth of the indicated target bacteria after addition of the indicated oligonucleotide as a function of time.

Figures 5(a and b) show the percent inhibition of the growth of the indicated target bacteria after addition of the 30 indicated oligonucleotide as a function of time.

Figures 6(a-t) are plots of log bacterial growth (and accompanying control cultures) as a function of time after the addition of the indicated oligonucleotide (*i.e.*, "NBT 114" indicates oligonucleotide sequence 114 (SEQ ID NO. 112) 35 from Table 1, *infra*). A clinical isolate of *Escherichia coli* ATCC accession No. 35218 (multiple drug resistant) was used in the experiments corresponding to figures 6(a-t).

Figures 7(a-j) are plots of log bacterial growth (and accompanying control cultures) of the penicillin resistant clinical isolate of *Staphylococcus aureus* ATCC accession No. 13301 as a function of time after the addition of the indicated oligonucleotide.

Figures 8 shows that animals challenged with the bacterial pathogen *Escherichia coli* show a significant increase in survival after treatment with oligonucleotide 114 (SEQ ID NO. 112) relative to nontreated control animals.

Figure 9 shows that test animals infected with the bacterial pathogen *Staphylococcus aureus* show a significant increase in survival after treatment with the variant of oligonucleotide 114 (SEQ ID NO. 112), SOT 114.21, relative to nontreated control animals.

Figures 10(a-b) show the results observed when the indicated antibacterial oligonucleotides were tested for bactericidal activity against *Staphylococcus aureus* using a standard overnight MIC assay.

Figures 11(a-b) show the results observed when the indicated antibacterial oligonucleotides were tested for bactericidal activity against *Serratia liquefaciens* using a standard overnight MIC assay.

Figure 12 shows the results obtained when the indicated antibacterial oligonucleotides were tested using a standard MIC assay against *Staph. aureus*.

Figure 13 shows the results obtained when a variety of different length versions of the indicated antibacterial oligonucleotide were tested using a standard MIC assay against *Staph. aureus*.

Figure 14 shows the results obtained when drug sensitive and drug resistant *Staph. aureus* were treated with oligonucleotide 114, and ampicillin.

Figure 15 shows the results of a standard MIC assay using oligonucleotide MMT 114.15 against *P. aeruginosa* strain 10145.

Figure 16 shows the results of a standard MIC assay using SOT 114.21 against *Strep. pyogenes* strain 14289.

4.0. DETAILED DESCRIPTION OF THE INVENTION

Prior to the present invention, clinically relevant bacterial pathogens were largely immune from treatment with antisense oligonucleotides. The reasons that the prior art oligonucleotides were ineffective against these pathogens include the dosages used, the lack of nuclease resistance of the oligonucleotide or the choice of the backbone, the length of the oligonucleotide, and the method of purification.

The present invention describes a method for generating oligonucleotides having the novel property of being capable of having bacteriostatic or bactericidal effects on clinically relevant bacterial pathogens. The oligonucleotides generated using the presently described methods are contemplated to be able to exert antibacterial effect both *in vitro* and *in vivo*. Typically, the antibacterial oligonucleotides will be targeted to bacterial sequences where, after associating with or binding to the target sequence, the oligonucleotide disrupts the normal function of the target sequence. The antibacterial effect of the oligonucleotide may be caused by either specific or nonspecific association as long as bacterial growth is inhibited.

Accordingly, particularly preferred embodiments of the present invention include the novel antibacterial oligonucleotides, methods of making the antibacterial oligonucleotides, and methods of using the novel antibacterial oligonucleotides to treat bacterial infection.

Given that bacterial infection is a particularly problematic complication in immunocompromised individuals such as patients suffering from acquired immunodeficiency disease syndrome (AIDS), HIV infected individuals, patients undergoing chemotherapy or radiation therapy, etc., an additional embodiment of the presently described invention is the use of the presently described antibacterial oligonucleotides to treat immunocompromised patients.

In a particularly preferred embodiment, the antibacterial oligonucleotides may be used to treat bacterial

infections in conjunction with similarly engineered antiviral oligonucleotides that are directed to any of a wide variety of human viruses including, but not limited to, adenovirus, human immunodeficiency virus, human leukemia virus, rhinovirus, herpes virus, human papilloma virus, respiratory syncytial virus, cytomegalo virus, Epstein bar virus, hepatitis virus (A, B, C and delta), etc. Accordingly, an additional embodiment of the presently described invention are mixed oligonucleotide compositions that comprise both antiviral and antimicrobial (e.g., antifungal, antibacterial, antiparasitic, etc.) oligonucleotides. Preferably, the relative ratios of the oligonucleotides present in such compositions shall be adjusted to target bacterial, parasitic, fungal, yeast, and viral pathogens that are generally associated as secondary infectious sequelae of infection by one another.

An additional embodiment of the present invention are therapeutic oligonucleotides that fuse one or more sequences with known antimicrobial, antibacterial, or antiviral therapeutic activity. Such fusions are deemed to constitute novel compositions having broad spectrum activity against multiple and distinct bacterial species, as well as broad antiviral and antibacterial activities. Similarly, oligonucleotides bearing multiple active sequences, or mixed compositions of antibacterial oligonucleotides, may be used to target the activity of a gene product in a pathogen by blanket targeting of the DNA (via triplex inhibition, disrupting DNA replication, etc.) and RNA (via RNase H activation or directly disrupting translation, etc.) encoding the activity of interest, as well as by aptameric inhibition of the gene product.

Where the therapeutic use of the presently described antibacterial oligonucleotides is contemplated, the antibacterial oligonucleotides are preferably administered in a pharmaceutically acceptable carrier, via oral, intranasal, rectal, topical, intraperitoneal, intravenous, intramuscular, subcutaneous, intracranial, subdermal, transdermal,

intrathecal methods, or the like. Typically, the preferred formulation for a given antibacterial oligonucleotide is dependent on the location of the target organism in the host animal or the location in a host where a given infectious
5 organism would be expected to initially invade.

For example, topical infections are preferably treated or prevented by formulations designed for topical application, whereas systemic infections are preferably treated or prevented by administration of compositions
10 formulated for parenteral administration. Additionally, pulmonary infections may be treated both parenterally and by direct application of the antibacterial oligonucleotides to the lung by inhalation therapy.

Additionally, as oligonucleotides are cleared from the
15 bloodstream, they can often accumulate at relatively high levels in the kidneys, liver, spleen, lymph glands, adrenal gland, aorta, pancreas, bone marrow, heart, and salivary glands. Oligonucleotides also tend to accumulate to a lesser extent in skeletal muscle, bladder, stomach, esophagus,
20 duodenum, fat, and trachea. Lower still concentrations are typically found in the cerebral cortex, brain stem, cerebellum, spinal cord, cartilage, skin, thyroid, and prostate (see generally Crooke, 1993, *Antisense Research and Applications*, CRC Press, Boca Raton, FL). Interestingly,
25 pathogenic bacteria also tend to accumulate in many of the above organs. Consequently, the presently described antibacterial oligonucleotides can be used to target bacterial infections in specific target organs and tissues.

One of ordinary skill will appreciate that, from a
30 medical practitioner's or patient's perspective, virtually any alleviation or prevention of an undesirable symptom (e.g., symptoms related to the presence of bacteria in the body) would be desirable. Thus, the terms "treatment", "therapeutic use", or "medicinal use" used herein shall refer
35 to any and all uses of the claimed antibacterial oligonucleotides which remedy a disease state or symptoms, or otherwise prevent, hinder, retard, or reverse the progression

of disease or other undesirable symptoms in any way whatsoever.

Preferably, animal hosts that may be treated using the oligonucleotides of the present invention include, but are not limited to, invertebrates, vertebrates, birds (such as chickens and turkeys, etc.) fish, mammals such as pigs, goats, sheep, cows, dogs, cats, and particularly humans.

When used in the therapeutic treatment of disease, an appropriate dosage of an antibacterial oligonucleotide, or mixture thereof, may be determined by any of several well established methodologies. For instance, animal studies are commonly used to determine the maximal tolerable dose, or MTD, of bioactive agent per kilogram weight. In general, at least one of the animal species tested is mammalian. Those skilled in the art regularly extrapolate doses for efficacy and avoiding toxicity to other species, including human. Before human studies of efficacy are undertaken, Phase I clinical studies in normal subjects help establish safe doses. Additionally, therapeutic dosages may also be altered depending upon factors such as the severity of infection, and the size or species of the host.

The presently described antibacterial oligonucleotides may also be complexed with molecules that enhance their ability to enter the target cells. Examples of such molecules include, but are not limited to, carbohydrates, polyamines, amino acids, peptides, lipids, and molecules vital to bacterial growth.

Additionally, the antibacterial oligonucleotide may be complexed with a variety of well established compounds or structures that, for instance, further enhance the *in vivo* stability of the oligonucleotide, or otherwise enhance its pharmacological properties (e.g., increase *in vivo* half-life, reduce toxicity, etc.).

The use of synthetic oligonucleotides are advantageous as an approach to treating bacterial infection because sequences can be specifically designed to inhibit bacterial

growth while not interfering with the metabolism of mammalian cells.

The present invention also relates to oligonucleotides that have demonstrated antibacterial activity *in vitro*. In particular, the oligonucleotides will have antibacterial activity as measured in a MIC (minimal inhibitory concentration) test that is recognized in the art as predictive of *in vivo* efficacy for the treatment of a bacterial infection with antibiotics. Without pretreatment of the bacteria to permeabilize them and without PEG-modification of the oligonucleotides, the oligonucleotides of the present invention are able to hybridize to a targeted region of a chosen bacterial polynucleotide (DNA or RNA) to effectively inhibit the ability of that polynucleotide to serve as a template for synthesis of its encoded product (DNA, RNA or protein), or otherwise inhibit the target sequence's normal function in the bacterium, thereby causing a bacteriostatic or bactericidal effect. Certain oligonucleotides may exert their bacteriostatic or bactericidal effects through binding to and inhibition of protein (aptameric effects).

In a preferred embodiment, the invention uses oligonucleotides that are substantially nuclease resistant. This includes oligonucleotides completely derivatized by phosphorothioate linkages, 2'-O-methylphosphodiester, p-ethoxy oligonucleotides, p-isopropyl oligonucleotides, phosphoramidates, chimeric linkages, and any other backbone modifications, as well as other modifications, which render the oligonucleotides substantially resistant to endogenous nuclease activity. Additional methods of rendering an oligonucleotide nuclease resistant include, but are not limited to, covalently modifying the purine or pyrimidine bases that comprise the oligonucleotide. For example, bases may be methylated, hydroxymethylated, or otherwise substituted (glycosylated) such that the oligonucleotides comprising the modified bases are rendered substantially nuclease resistant.

The present invention further relates to compositions comprising nuclease resistant antibacterial oligonucleotides. These compositions generally comprise the oligonucleotide (or a mixture of oligonucleotides) and a physiologically acceptable carrier. After administration, the oligonucleotides enter the bacterial cell and bind to the target. The target may be a polynucleotide where hybridization to the oligonucleotide results in an inability of the polynucleotides to serve as templates for their encoded products. When the target is a protein, the bound oligonucleotide protein complex is inhibited relative to normal protein function (aptameric effect). As a result, growth of the bacteria are inhibited and the effects of the bacteria on the animal are less than they would have been if the oligonucleotides had not been administered.

Optionally, the presently described antibacterial oligonucleotides may be formulated with a variety of physiological carrier molecules. For example, the antibacterial oligonucleotides may be combined with a lipid (or cationic lipid), the resulting oligonucleotide/lipid emulsion, or liposomal suspension may, *inter alia*, effectively increase the *in vivo* half-life of the oligonucleotide. The use of cationic, anionic, and/or neutral lipid compositions or liposomes is generally described in International Publications Nos. WO 90/14074, WO 91/16024, WO 91/17424, Pat. No. 4,897,355, herein incorporated by reference.

The antibacterial oligonucleotides of the present invention may also be introduced into bacteria after being complexed with cationic lipids such as DOTMA (which may or may not form liposomes) which complex is then contacted with the target cells. Suitable cationic lipids include, but are not limited to, N-(2,3-di(9-(Z)-octadecenyloxy))-prop-1-yl-N,N,N-trimethylammonium (DOTMA) and its salts, 1-O-oleyl-2-O-oleyl-3-dimethylaminopropyl- β -hydroxyethylammonium and its salts and 2,2-bis (oleyloxy)-3-(trimethylammonio) propane and its salts. By assembling the antibacterial oligonucleotides

into lipid-associated structures, the antibacterial oligonucleotides may be targeted to specific bacterial cell types by the incorporation of suitable targeting agents (i.e., specific antibodies or receptors) into the
5 oligonucleotide/lipid complex.

In another embodiment, the presently described purified oligonucleotides may be complexed with additional antibacterial agents. Additionally, the described nuclease resistant antibacterial oligonucleotides may also be linked
10 to a conventional antibiotic or other chemical group that inhibits bacterial gene expression.

Having a demonstrated activity *in vitro*, the presently described antibacterial oligonucleotides are also contemplated to be effective in combating bacterial
15 contamination of laboratory cultures, consumables (food or beverage preparations), or industrial processes.

4.1. Definitions

For the purposes of the present disclosure, the term
20 "oligonucleotide" typically refers to a molecule comprising from about 8 to about 80 nucleotides, preferably about 15 to about 35 nucleotides, including polymers of ribonucleotides, deoxyribonucleotides, or both, with the ribonucleotide and/or deoxyribonucleotides being connected together via 5' to 3'
25 linkages that may include any of the linkages known in the oligonucleotide art (including, for example, oligonucleotides comprising 5' to 2' linkages). In general, longer oligonucleotides (about 50 nucleotides) display enhanced targeting specificity but may be less efficient gaining entry
30 to the target bacterium. Conversely, shorter oligonucleotides may more easily permeate the target bacteria, but may display a tendency to nonspecifically associate with host sequences and create a bystander effect or have no effect at all. Additionally, shorter
35 oligonucleotides may less efficiently bind to, and thus nonspecifically inhibit, bacterial target sequences. For example, shorter antisense oligonucleotides (6mers to 7mers)

may prove less efficient at specifically binding the target mRNA, and may prove less efficient at activating RNase H activity. Shorter oligonucleotides may also effect host gene expression in a nonspecific, and thus undesirable, manner.

5 In spite of the above, the present application additionally contemplates relatively short oligonucleotide sequences (6mers to 7mers) having the desired antibacterial effects, and preferably broad-spectrum antibacterial effects, while exhibiting few adverse side effects in the host. In
10 fact, an example of a short (6mer) oligonucleotide is provided below that exhibits significant antibacterial activity and is contemplated as a specific example of a preparation of an antibacterial oligonucleotide that functionally defines the lower size limit of the present
15 invention. Given that the present invention specifically contemplates short oligonucleotides with demonstrated antibacterial function, the short oligonucleotides of the present invention specifically exclude short inoperative oligonucleotides such as AGGAGGT or GGAG.

20 Accordingly, additional embodiments of the present invention include relatively short (e.g. 6mers) oligonucleotides that have been identified by using the presently disclosed methods of synthesis in conjunction with standard antibacterial assays while gradually deleting bases
25 from oligonucleotides with established antibacterial activity in order to define short antibacterial "core" sequences.

A particular embodiment of the present application contemplates oligonucleotides that have been modified to enhance the specificity of binding. Increased specificity
30 allows for shorter oligonucleotides having the desirable features of both long and short oligonucleotides.

The presently described oligonucleotides may be constructed using either conventional bases (adenosine, cytosine, guanosine, thymidine, xanthine, inosine, or
35 uridine) or any other modified bases, or base analogues that allow an oligonucleotide comprising such analogues to retain its ability to hybridize to a complementary nucleotide

sequence. Examples of such non-naturally occurring bases that are capable of forming base-pairing relationships with naturally occurring nucleotide bases include, but are not limited to, aza and deaza pyrimidine analogues, aza and deaza
5 purine analogues as well as other heterocyclic base analogues, wherein one or more of the carbon and nitrogen atoms of the purine and pyrimidine rings have been substituted by heteroatoms, e.g., oxygen, sulfur, selenium, phosphorus, and the like.

10 Modified oligonucleotides, nuclease resistant oligonucleotides, and antisense oligonucleotides are also meant to be encompassed by this definition. The term "oligonucleotide" is meant to encompass all of the foregoing, unless the context dictates otherwise.

15 The term "modified oligonucleotide" refers to oligonucleotides that include one or more modifications of the nucleic acid bases, sugar moieties, internucleoside phosphate linkages, as well as molecules having added substituents, such as diamines, cholesteryl or other
20 lipophilic groups, or a combination of modifications at these sites. The internucleoside phosphate linkages can be phosphodiester, phosphotriester, phosphoramidate, siloxane, carbonate, carboxymethylester, acetamidate, carbamate, thioether, bridged phosphoramidate, bridged methylene
25 phosphonate, bridged phosphoramidate, bridged phosphoramidate, bridged methylene phosphonate, phosphorothioate, methylphosphonate, phosphorodithioate, bridged phosphorothioate and/or sulfone internucleotide linkages, or 3'-3' or 5'-5' linkages, and combinations of
30 such similar linkages (to produce mixed backbone modified oligonucleotides). The modifications can be internal or at the end(s) of the oligonucleotide molecule and can include additions to the molecule of the internucleoside phosphate linkages, such as cholesteryl, diamine compounds with varying
35 numbers of carbon residues between amino groups and terminal ribose, deoxyribose and phosphate modifications which cleave or cross-link to the opposite chains or to associated enzymes

or other proteins. Electrophilic groups such as ribose-dialdehyde could covalently link with an epsilon amino group of the lysyl-residue of such a protein. A nucleophilic group such as n-ethylmaleimide tethered to an oligomer could covalently attach to the 5' end of an mRNA or to another electrophilic site. The term modified oligonucleotides also includes oligonucleotides comprising modifications to the sugar moieties such as 2'-substituted ribonucleotides, or deoxyribonucleotide monomers, any of which are connected together via 5' to 3' linkages. The term "modified oligonucleotide" is meant to encompass all of the foregoing, unless the context dictates otherwise, and also refers to oligonucleotides comprising chemical groups (e.g., sugar molecules, amino acids, etc.) that may improve the antibacterial activity of the oligonucleotide.

The term "oligonucleotide backbone" refers to any and all means of chemically linking nucleotides such that oligonucleotides result that are capable of base-pairing or otherwise hybridizing, or interacting with a bacterial target sequence in a more-or-less sequence specific manner.

The term "purified oligonucleotide" refers to an oligonucleotide that has been isolated so as to be substantially free of, *inter alia*, incomplete oligonucleotide products produced during the synthesis of the desired oligonucleotide. Preferably, a purified oligonucleotide will also be substantially free of contaminants which may hinder or otherwise mask the antibacterial activity of the oligonucleotide. In general, where an oligonucleotide is able to bind to, or gain entry and inhibit the growth of a bacteria, it shall be deemed as substantially free of contaminants that hinder antibacterial activity. One example of a method to produce such purified oligonucleotides is described herein. In particular, an oligonucleotide preparation shall generally be considered substantially free of adverse contaminants (e.g., contaminants that hinder the measured antibacterial activity of the nucleotides such as alkyl amines, alkyl ammonium groups, or agents that block

- oligonucleotide entry, etc.) when the sample proves effective in an *in vitro* MIC assay to an extent that displays more than about twice, and preferably about five times, and most preferably at least about an order of magnitude greater
- 5 antibacterial activity than a corresponding preparation that has not been treated to remove the adverse contaminants. Typically, an oligonucleotide preparation shall preferably be considered substantially free of adverse contaminants when the levels of contaminants in a sample are reduced to about
- 10 1/20th of the levels found in unpurified (or intermediately purified) samples, more typically about 1/50th of the levels found in unpurified samples, and preferably less than about 1/100th of the levels found in intermediately or unpurified samples of oligonucleotide.
- 15 Alternatively, an antibacterial oligonucleotide preparation may generally be considered free of adverse contaminants when the composition is about 95 percent free, and specifically about 99 percent free of contaminating alkyl amines, alkyl ammonium groups, or a mixture thereof as
- 20 compared to unpurified crude or intermediately purified samples of the oligonucleotide preparation (as measured by conductivity, mass spectroscopy, or the extent to which a given oligonucleotide preparation retains antibacterial activity).
- 25 The term "substantially nuclease resistant" refers to oligonucleotides that are resistant to nuclease degradation, as compared to unmodified oligonucleotides, and include, but are not limited to oligonucleotides with modified backbones, such as, for example, phosphorothioates, methylphosphonates,
- 30 ethylphosphotriesters, 2'-O-methylphosphorothioates, 2'-O-methyl-p-ethoxy ribonucleotide, 2'-O-methyl ribonucleosides, methyl carbamates, and methyl carbonates, inverted bases or chimeric versions of these backbones. Typically, the relative nuclease resistance of an oligonucleotide will be
- 35 measured by comparing the percent digestion of a resistant oligonucleotide with the percent digestion of its unmodified counterpart (i.e., a corresponding oligonucleotide with

"normal" backbone, bases, and phosphodiester linkage). Such nuclease resistance tests generally add a given concentration of oligonucleotide (e.g., about 121 μ molar) to a given amount of nuclease S1 (at about 0.05 units per ml final concentration in the reaction), P1 (at about 0.05 units per ml final concentration in the reaction), SVP (at about 0.05 units per ml final concentration in the reaction), Micrococcal Nuclease (at about 0.5 units per ml final concentration in the reaction), etc., and measure the percent degradation (all reactions are incubated at about 37°C in the buffer appropriate for each nuclease. For example, S1 nuclease digestion conditions are typically 30 mM sodium acetate (pH 4.5), 50 mM NaCl, 1 mM ZnCl₂, 5% Glycerol; P1 nuclease digestion conditions are typically 30 mM sodium acetate (pH 5.3), 0.2 mM ZnCl₂; SVP digestion conditions were 100 mM Tris (pH 8.9) 100 mM NaCl, 14 mM MgCl₂; and Micrococcal nuclease digestion conditions are typically 50 mM sodium borate (pH 8.8), 5 mM NaCl, 2.5 mM CaCl₂). Percent degradation may be determined by using analytical HPLC to assess the loss of full length oligonucleotide, or by any other suitable methods (e.g., by visualizing the products on a sequencing gel using staining, autoradiography, fluorescence, etc., or measuring a shift in optical density). Degradation is generally measured as a function of time.

Generally, a substantially nuclease resistant oligonucleotide will be at least about 25% more resistant to nuclease degradation than an unmodified oligonucleotide with a corresponding sequence, typically at least about 50% more resistant, preferably about 75% more resistant, and more preferably at least about an order of magnitude more resistant after 15 minutes of nuclease exposure.

The term "targeted to a bacterial sequence" refers to the fact that the presently described antibacterial oligonucleotides are substantially homologous, otherwise complementary, or capable of associating with a target bacterial sequence. By associating with the target bacterial sequence, the presently described antibacterial

oligonucleotides are able to disrupt or inhibit the normal function of the target sequence, and hence inhibit bacterial cell division. In general, the antibacterial oligonucleotides will associate or bind to the target
5 bacterial sequence and inhibit the function of the sequence by an antisense mechanism, an antigene (triplex) mechanism, or by steric hindrance. Furthermore, the oligonucleotides can function through an aptameric mechanism by binding to nucleic acid binding proteins. For the purposes of the
10 present invention, the term "aptamer" shall refer to oligonucleotides that are capable of binding or otherwise interacting with peptides, polypeptides, or proteins in a manner that effects the normal function of the peptide, polypeptide, or protein.

15 In order for the presently described antibacterial oligonucleotides to recycle their antibacterial activity, the oligonucleotides will generally associate with bacterial target sequences with an avidity sufficient to elicit an antibacterial effect, yet weak enough to allow the
20 oligonucleotide to disassociate from the reaction products (e.g., after messenger degradation, etc.) and subsequently target another molecule. One method of reducing the binding avidity, or relaxing the binding specificity, of an oligonucleotide is to truncate, or delete, a portion of the
25 oligonucleotide.

Alternatively, another method of relaxing the binding avidity of an oligonucleotide comprises engineering a percentage of miss-match (or more-or-less neutral match, e.g., G-U base pairs) into the antibacterial nucleotide
30 sequence. By reducing the net homology of a sequence, one effectively allows for antibacterial activity while increasing the kinetics of disassociation. Accordingly, an additional embodiment of the presently claimed methods and oligonucleotides are relaxed-specificity antibacterial
35 oligonucleotides which comprise sequence miss-matches (with the corresponding target sequence) of up to about 60 percent, often about 35 percent, and preferably about 20 percent, or

less. In spite of the percentage miss-match, the relaxed-specificity oligonucleotides remain capable of associating with bacterial target sequences under physiological temperatures and conditions. For the purposes of the present invention, the term "miss-match" shall apply to all Watson and Crick polynucleotide base-pairs, other than A:T, G:C, and A:U, and the inverses thereof.

Furthermore, one of ordinary skill will appreciate that the maximally tolerated percentage miss-match may vary depending on the G/C content of the oligonucleotide. In general, an A/T-rich sequence may tolerate a fairly high percentage of miss-match where the G/C base pairs have been retained. In any event, the amount of sequence miss-match should not be such that undue side effects result in the host.

Additionally, given the reduced charge associated with oligonucleotides comprising partially or fully substituted chemical backbones, it is to be understood that such oligonucleotides may retain the ability to bind target bacterial sequence under physiological conditions although comprising a greater amount of sequence miss-match than may be tolerated by conventional oligonucleotides.

An additional embodiment of the present invention is antibacterial oligonucleotides that are capable of inhibiting bacterial growth by cross reacting with a variety of both known and unknown bacterial target sequences. For the purposes of the present disclosure, the term "cross reactive antibacterial oligonucleotide" shall refer to an oligonucleotide sequence that inhibits bacterial growth by interacting with bacterial sequences that may share less than 100 percent sequence homology, and preferably at least about 50 percent sequence homology, with the oligonucleotide. Examples of such a cross reactive antibacterial activity include: instances where heterologous, similar, and homologous bacterial sequences are bound and affected by an oligonucleotide that is targeted to a related sequence; instances where an antibacterial oligonucleotide is able to

interact with bacterial sequences that share a sufficient percentage of otherwise random sequence complementarity (e.g., short, interspersed regions of high sequence complementarity, etc.) with the oligonucleotide such that
5 bacterial growth is inhibited; and instances where a given antibacterial oligonucleotide is able to inhibit bacterial growth although all or some of the affected bacterial target sequences are unknown (this includes instances where the cross reactive oligonucleotide has up to 100% homology with
10 an unknown target DNA sequence). Target sequences comprised within conserved or related control regions, which are often noncoding, are deemed to constitute particularly effective targets for cross reactive antibacterial oligonucleotides that operate via an antigene mechanism.

15 A "functional equivalent" of the sequences disclosed in the Sequence Listing shall include any oligonucleotides comprising sequence that is at least about 25 percent sequence homologous, preferably about 33 percent sequence homologous, and more preferably at least about 50 percent
20 homologous to any one of SEQ ID NOS. 1-176, and demonstrates at least about 30 percent, and preferably at least about 50 percent of the antibacterial activity of the corresponding oligonucleotide in the Sequence Listing when measured in an MIC assay.

25 The term "bacterial sequence" includes any and all forms of DNA, RNA or amino acid polymers (or oligomers) that are present in the cell.

The term "competent cells" refers to bacterial cells that have been manipulated in culture or otherwise
30 chemically, osmotically, or thermally modified such that the cells bear an enhanced ability to internalize exogenous nucleic acid.

The term "pathogenic bacteria" refers to any and all bacteria that are, or have been, associated with clinical
35 symptoms of disease in animals, including humans. The term "wild-type" bacteria refers to a bacteria that has not been modified either chemically or genetically in any way

whatsoever (other than growth in culture medium). In particular, a "wild-type" bacteria shall not be genetically modified such that the bacteria has an enhanced permeability to macromolecules or biological polymers or oligomers.

5 The term "antisense oligonucleotide" refers to an oligonucleotide that has a sequence that is substantially complementary to a target DNA or mRNA, so that the antisense oligonucleotide will hybridize in a complementary fashion to the DNA or mRNA to form a complex by Watson-Crick base
10 pairing. Generally, the antisense oligonucleotide will bind the complementary target sequence with an avidity, *in vivo*, sufficient to inhibit the normal function of target sequence.

 The term "bacteriostatic oligonucleotide" refers to oligonucleotides that inhibit or retard the growth of
15 bacteria either *in vitro* or *in vivo*.

 The term "bactericidal oligonucleotide" refers to oligonucleotides that directly, or indirectly, cause the death of bacteria either *in vitro* or *in vivo*.

 The term "Gram negative bacteria" refers to the
20 inability of bacteria to resist decolorization with alcohol after being treated with Gram's crystal violet stain. However, following decolorization, these bacteria can be readily counter-stained with safranin, imparting a pink or red color to the bacterium when viewed by light microscopy.
25 This reaction is usually an indication that the bacterium's outer structure consists of a cytoplasmic membrane (inner), which is surrounded by a relatively thin peptidoglycan layer, which in turn, is surrounded by an outer membrane. Typical examples of Gram negative bacteria include, but are not
30 limited to, *Escherichia*, *Salmonella*, *Edwardsiella*, *Arizona*, *Citrobacter*, *Enterobacter*, *Proteus*, *Yersinia*, *Klyvera*, *Klebsiella*, *Neisseria*, *Vibrio*, *Pasturella*, *Haemophilus*, *Pseudomonas*, *Moraxella*, *Eikenella*, *Fusobacterium*, *Acidominococcus*, *Actinobacillus*, *Cardiobacterium*, *Serratia*,
35 *Providencia*, *Erwinia*, *Tatumella*, *Shigella*, *Branhamella*, *Aeromonas*, *Francisella*, *Gardnerella*, *Alcaligenes*, *Kingella*, *Agrobacterium*, *Leptotrichia*, *Megasphaera*, *Capnocytophaga*,

Cromobacterium, *Hafnia*, *Morganella*, *Pectobacterium*, *Cadecea*, *Helicobacter*, *Morococcus*, *Pleisiomonas*, *Bordetella*, *Brucella*, *Achromobacter*, *Flavobacterium*, *Bacteroides*, *Veillonella*, *Streptobacillus*, *Pneumococcus*, and *Calymmatobacterium*.

- 5 The term "Gram positive bacteria" refers to the ability of bacteria to resist decolorization with alcohol after treatment with Gram's crystal violet stain, imparting a violet color to the bacterium when viewed by light microscopy. This reaction is usually an indication that the
- 10 bacterium's outer structure consists of a cytoplasmic membrane surrounded by a thick, rigid bacterial cell wall mainly comprised of peptidoglycan (murein). Typical examples of Gram positive bacteria include, but are not limited to, *Aerococcus*, *Listeria*, *Streptomyces*, *Actinomadura*,
- 15 *Lactobacillus*, *Eubacterium*, *Arachnia*, *Mycobacterium*, *Peptostreptococcus*, *Staphylococcus*, *Corynebacterium*, *Erysipelothrix*, *Dermatophilus*, *Rhodococcus*, *Bifodobacterium*, *Lactobacillus*, *Streptococcus*, *Bacillus*, *Peptococcus*, *Micrococcus*, *Kurthia*, *Nocardia*, *Nocardiopsis*, *Rothia*,
- 20 *Propionibacterium*, *Actinomyces*, *Enterococcus*, and *Clostridia*.

Additionally, the presently described antibacterial oligonucleotides may be effective against bacteria including, but not limited to, *Campylobacter*, *Spirillum*, *Borrelia*, *Treponema*, *Leptospira*, *Legionella*, and *Chlamydia*.

- 25 The term "mycobacterium" refers to any and all strains of bacteria drawn from the group comprising: *Mycobacterium tuberculosis*, *Mycobacterium bovis*, *Mycobacterium leprae*, *Mycobacterium avium-intracellulare*, *Mycobacterium kansasii*, *Mycobacterium scrofulaceum*, *Mycobacterium marinum*,
- 30 *Mycobacterium fortuitum*, *Mycobacterium ulcerans*, *Mycobacterium chelonae*, *Mycobacterium paratuberculosis*, *Mycobacterium xenopi*, *Mycobacterium simiae*, or other mycobacteria falling within the Runyon groups I-IV as described in Runyon, Med. Clin. North Amer. 43:273-290
- 35 (1959), or Mandell et al., 1990, Principles and Practice of Infectious Disease 3rd. ed., Churchill Livingstone Inc., New York, N.Y. 10036, herein incorporated by reference.

The term "MIC test" refers to a National Committee on Clinical Laboratory Standards ("NCCLS") approved test for determining the minimum inhibitory concentrations ("MIC") of bacteria by broth dilution. This term includes the use of this test for determining the percent inhibition of bacterial growth by the oligonucleotides of the invention.

The term "transport" refers to the movement of the oligonucleotides of the invention from outside the bacterial cell across the bacterial cell's outer-structure and into the bacterial cell's cytoplasm.

The term "virulence factor" refers to bacterial products which contribute to the pathogenicity of a bacteria, such as, for example, antibiotic resistance factors, toxins (exo- and endo-), adherence factors that recognize host tissues, extracellular receptors, bacterial iron-binding proteins, and surface modifications that allow the bacteria to escape the immune system (e.g., polysaccharide coats or capsules).

The term "labeled oligonucleotides" refers to oligonucleotides that have been modified to allow a determination of the presence or amount of the oligonucleotide. Typical labels include, for example, radioisotopes, biotin, and enzymes (such as luciferase, or β -galactosidase).

The term "stringent conditions" generally refers to hybridization conditions that (1) employ low ionic strength and high temperature for washing, for example, 0.015 M NaCl/0.0015 M sodium citrate/0.1% SDS at 50°C.; (2) employ during hybridization a denaturing agent such as formamide, for example, 50% (vol/vol) formamide with 0.1% bovine serum albumin/0.1% Ficoll/0.1% polyvinylpyrrolidone/50 mM sodium phosphate buffer at pH 6.5 with 750 mM NaCl, 75 mM sodium citrate at 42°C; or (3) employ 50% formamide, 5 x SSC (0.75 M NaCl, 0.075 M Sodium pyrophosphate, 5 x Denhardt's solution, sonicated salmon sperm DNA (50 g/ml), 0.1% SDS, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC and 0.1% SDS. The above examples of hybridization conditions are merely provided for purposes of exemplification and not

limitation. One of ordinary skill will appreciate that stringency may generally be reduced by increasing the salt content present during hybridization and washing, reducing the temperature, or a combination thereof. A more thorough
5 treatise of such routine molecular biology techniques may be found in Sambrook et al., Molecular Cloning, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, Vols. 1-3 (1989), and periodic updates thereof, herein incorporated by reference.

10

4.2. Synthesis Of Oligonucleotides

The described oligonucleotides may be partially or fully substituted with any of a broad variety of chemical groups or linkages including, but not limited to: phosphoramidates,
15 phosphorothioates; p-ethoxy; alkyl phosphonate; 2'-O-methyl; 2' modified RNA; morpholino groups; phosphate esters; dithioates; 5' thio groups; propyne groups; or chimerics of any combination of the above groups or linkages (or analogues thereof), or any other chemical modifications that leave the
20 oligonucleotide capable of specifically binding to nucleic acid or protein.

Oligonucleotides, methylphosphonates, and phosphorothioates may be synthesized, using standard reagents and protocols, on an automated synthesizer utilizing methods
25 that are well known in the art, such as, for example, those disclosed in Stec et al., J. Am. Chem. Soc. 106:6077-6089 (1984), Stec et al., J. Org. Chem. 50(20):3908-3913 (1985), Stec et al., J. Chromatog. 326:263-280 (1985), LaPlanche et al., Nuc. Acid. Res. 14(22):9081-9093 (1986), and Fasman,
30 G.D. Practical Handbook of Biochemistry and Molecular Biology, 1989, CRC Press, Boca Raton, Florida, herein incorporated by reference.

The principal criteria for designing nuclease resistant oligonucleotides are: (1) retention of sequence-specific
35 base-pairing and triplex-forming interactions (i.e., the ability to associate with bacterial target sequence such that bacterial growth is inhibited); (2) increasing nuclease

stability; (3) ease of synthesis and purification. The most common strategies to date have involved neutralizing the charge on the phosphodiester backbone by substitution at, or replacement of, the phosphodiester moiety, conjugating 5 moieties at the 3' and/or 5' terminus, and substitutions at the 2'-position of ribose and deoxyribose. In particular, the addition of a 3'-3' or 5'-5' internucleotidic linkages at either end of the oligonucleotide, may inhibit degradation by the respective exonuclease (Seliger et al., 1991, Nucleosides 10 and Nucleotides, 10:463-477). Additionally, several new strategies have recently emerged that utilize peptide interlinkages.

The synthesis of phosphoramidates is disclosed in Agrawal et al., Proc. Natl. Acad. Sci. USA 85:7079-7083 15 (1988). The preparation of phosphoramidates modified with several methoxyethyl phosphoramidate internucleoside linkages is disclosed in Dagle et al., Nucl. Acids Res. 18(6):4751-4757 (1990). These modified oligonucleotides are highly resistant to nucleolytic degradation and can also serve as a 20 substrate for RNase H (which degrades the RNA component of a DNA/RNA hybrid).

An approach for synthesizing formacetal linked dinucleosides is disclosed by Quaedflieg et al., Tetrahedron Lett. 33(21):3081-3084 (1992).

25 The synthesis and binding properties of pyrimidine oligonucleotides containing alternating modified and natural internucleoside linkages, formacetal and thioformacetal, is disclosed by Jones et al., J. Org. Chem. 58:2983-2991 (1993). The thioformacetal modified oligodeoxynucleotides (ODN) 30 displayed high affinity and specificity for both single-stranded RNA and double-stranded DNA targets, indicating that this linkage is promising for both antisense and triplex (antigene) therapeutic applications.

The synthesis of hexanucleotide analogues containing 35 internucleotide diisopropylsilyl linkages is disclosed by Cormier and Ogilvie, Nucl. Acids Res. 16(10):4583-4594 (1988). These oligonucleotides were not readily soluble in

water. It has been suggested that inserting terminal or internal phosphodiester groups, or highly hydrophilic groups would increase water solubility of these compounds.

The synthesis of acetamidate linked oligomers of mean 5 chain length 10-13 is disclosed by Gait et al., J. Chem. Soc., Perkin Trans. 1:1684 (1974).

The synthesis of dinucleotides and trinucleotides modified with carbamate (-OCO-NH-) bonds is disclosed by Mungall and Kaiser, J. Org. Chem. 42(4):703-706 (1977). The 10 carbamate linkage was found to be stable toward acid and base hydrolysis, as well as toward nucleases.

The synthesis of oligonucleotides with dimethylene-sulfide (-CH₂-S-CH₂), -sulfoxide (-CH₂-SO-CH₂), and -sulfone (-CH₂-SO₂-CH₂) groups replacing phosphodiester linkages is 15 reported by Schneider and Brenner, Tetrahedron Lett. 31(3):335-338 (1990); Huang et al., J. Org. Chem. 56:3869-3882 (1991); Musicki et al., Tetrahedron Lett. 32(10):1267-1270 (1991); Huang et al., Tetrahedron Lett. 33(19):2657-2660 (1992); and Reynolds et al., J. Org. Chem. 57:2983-2985 20 (1992).

The synthesis of 2'-O-alkyloligoribonucleotides, where the alkyl groups are methyl, butyl, allyl or 3,3-dimethylallyl is reviewed by Lamond, Biochem. Soc. Trans. 21:1-8 (1993). Oligomers comprised of the modified linkages 25 formed stable duplexes that exhibited a higher T_m (upon binding complementary RNA) than unmodified RNA-RNA duplexes. Oligonucleotides containing the modified linkages are nuclease resistant. It was found that binding of allyl-modified oligomers to A/U rich mRNA sequences (typical of 30 snRNAs) could be improved by incorporating the modified base 2-aminoadenine in the modified probe.

The synthesis of 2'-deoxyuridine analogues carrying an amino linker at the 1'-position of deoxyribose is disclosed by Ono et al., Bioconjugate Chem. 4:499-508 (1993). The 35 uridine analogues were incorporated into oligonucleotides and intercalating groups such as anthraquinone and pyrene derivatives that were attached to the amino group of the

linker. Several oligonucleotides were synthesized that incorporated the analogues at several different sequence positions. Duplexes formed with the analogues were more stable than unmodified duplexes. Also, the oligonucleotide analogues were resistant to exo- and endonuclease degradation. Moreover, duplexes formed with the analogues were capable of activating RNase H. The authors suggested that the bulky group attached at the C1'-position sterically masked the phosphodiester linkage from nuclease attack.

10 The synthesis of uniformly modified 2'-deoxy-2'-fluoro phosphorothioate oligonucleotides is disclosed by Kawasaki et al., J. Med. Chem. 36:831-841 (1993). Since 2'-deoxy-2-fluororibose adopts the 3'-endo conformation, it was hypothesized that deoxy oligomers modified at the 2'-position
15 with fluorine would adopt more uniform and more stable duplexes with RNA. The modified oligomers were found to possess thermal stabilities similar to or higher than those of the corresponding RNA duplexes. The modified oligomers demonstrated resistance to nucleases, but did not activate
20 RNase H.

A description of the synthesis of p-ethoxy-linked oligonucleotides may be found, *inter alia*, in application Ser. No. 08/065,016, filed May 24, 1993, herein incorporated by reference. The synthesis of inverted bases is described
25 in Seliger et al..

Additional antibacterial oligomers may be adapted from the polynucleotide binding polymers and backbones described in Pat. Nos. 5,034,506, 5,142,047, 5,166,315, 5,185,444, 5,470,974, and 5,235,033, which are herein incorporated by
30 reference.

The synthesis of oligonucleotides containing any of the above internucleotide linkages is well known to those skilled in the art, as is further illustrated in articles by Uhlmann et al., Chem. Rev. 90:543-584 (1990), and Schneider et al.,
35 Tetrahedron Lett. 31:335 (1990). See also Reissue Pat. No. 34,069, herein incorporated by reference.

4.2.1 Oligonucleotides Comprising Modified Nucleosides α -Anomeric Nucleoside Units.

The synthesis of a octathymidylate comprised of α -anomers is disclosed by Thuong et al., Proc. Natl. Acad. Sci. USA 84:5129-5133 (1987). The modified oligomer binds to complementary sequences containing naturally occurring β anomers. A 3'-acridine linked α -anomer was also prepared. This analogue also demonstrated sequence-specific binding. The α -anomers demonstrated nuclease stability, independently of whether linked to acridine or not.

Base-Modified Nucleoside Units. The synthesis of a base analogue designed to recognize T-A and G-C Watson-Crick base pairs to facilitate sequence-specific triplex formation is disclosed by Griffin et al., J. Am. Chem. Soc. 114:7976-7982 (1992).

4.3. Purification Of Oligonucleotides

The present disclosure teaches that the relative purity of an antibacterial oligonucleotide may profoundly impact its antibacterial activity. As discussed in greater detail below, the antibacterial activity of an oligonucleotide may be enhanced by at least 60 percent after it has been subject to an appropriate purification protocol. It is particularly important that purification remove contaminants that either obstruct the uptake of the oligonucleotides or mask the antibacterial activity of the oligonucleotides by, for example, stimulating bacterial growth.

A variety of standard methods were used to purify/produce the presently described antibacterial oligonucleotides. In brief, the antibacterial oligonucleotides of the present invention were purified by chromatography on commercially available reverse phase (for example, see the RAININ Instrument Co., Inc. instruction manual for the DYNAMAX®-300A, PureDNA™ reverse-phase columns, 1989, or current updates thereof, herein incorporated by reference) or ion exchange media (see generally, Warren and Vella, 1994, "Analysis and Purification of Synthetic

Oligonucleotides by High-Performance Liquid Chromatography",
In Methods in Molecular Biology, vol. 26: Protocols for
Oligonucleotide Conjugates, S. Agrawal ed., Humana Press,
Inc., Totowa, NJ; Aharon et al., 1993, J. Chrom. 698:293-301;
5 and Millipore Technical Bulletin, 1992, "Antisense DNA:
Synthesis, Purification, and Analysis"). Peak fractions were
combined and the samples were desalted and concentrated by
alcohol (ethanol, butanol, isopropanol, and isomers and
mixtures thereof, etc.) precipitation, diafiltration, or gel
10 filtration followed by lyophilization, or solvent evaporation
under vacuum in commercially available instrumentation such
as, for example, a Savant Speed Vac.

Oligonucleotides of the invention were dissolved in
pyrogen free, sterile, physiological saline (i.e., 0.85%
15 saline) and sterile filtered through 0.2 micron pyrogen free
filters.

4.4. Oligonucleotides As Antibiotics

The principal criteria for designing antisense
20 oligonucleotides for treating bacterial infections are: (1)
retention of sequence-specific base-pairing and triplex-
forming interactions; (2) increasing nuclease stability; (3)
increasing the extent or kinetics of entry into the target
cell; (4) activating RNase H (while a consideration, a given
25 oligonucleotide's ability to activate RNase H is not strictly
required to observe antibacterial activity); and (5) ease of
synthesis and purification.

Although exquisite sequence specificity may be preferred
in some instances, the presently described oligonucleotides
30 are capable of specifically inhibiting bacterial growth as
long as they remain capable of associating with the target
sequence under the relevant conditions. For example, the use
of oligonucleotides to degrade RNA simply requires that the
oligonucleotide associate (with at least a four base match)
35 with the bacterial RNA long enough to activate RNase H.
Thus, oligonucleotides that harbor relaxed sequence
specificity are deemed sufficient to activate RNase H. In

fact, because not all bacterial target sequences are known, applications are contemplated where the antibacterial oligonucleotide provides the desired inhibitory effect although not specifically targeted, or homologous, to a given bacterial gene.

Modified oligonucleotides that activate RNase H are advantageous because such oligonucleotides will hybridize to their target mRNAs and create a substrate that can be digested by RNase H. RNase H digestion destroys the target mRNA, and thus, these oligonucleotides prevent the translation of the target mRNA. Accordingly, protein expression is inhibited either by the enzymatic destruction of the target mRNA, or by the oligonucleotide physically blocking translation (i.e., after the oligonucleotide directly associates with ribosomal sequence).

Although RNase H activation is a factor in the design of antibacterial oligonucleotides, many antibacterial oligonucleotides (e.g., ribonucleotides targeting bacterial RNA) are not designed to activate RNase H. Typically, modified oligonucleotides that are connected by stretches of unmodified phosphodiester linkages comprising at least about four nucleotides to about seven nucleotides should retain the ability to activate RNase H. Also, it has been observed that phosphorothioate ribonucleotides can also activate RNAase H digestion. The differential specificity of mammalian RNase H (minimum of 5 bases) and bacterial RNAase (4 bases) affords a means of selectively targeting bacterial genes that may have strong sequence homology with certain animal genes.

Also contemplated are modified oligonucleotides that can form triplexes with duplex DNA (antigene oligonucleotides), and oligonucleotides that can be used as ribozymes.

Another embodiment of the presently described antibacterial oligonucleotides is aptameric oligomers that are capable of effectively mimicking protein domains and exerting an antibacterial effect by directly associating with bacterial proteins or structures.

Additionally, antibacterial oligonucleotides may exert a therapeutic effect by specifically binding and deactivating cellular machinery. For example, the presently described oligonucleotides may directly bind ribosomal sequences and inhibit translation by sterically hindering translation initiation, elongation, disassociation, or by directly destabilizing the structure of the bacterial ribosomes.

Antibiotic resistance is often caused by the presence of resistance factors that render an antibiotic ineffective. By targeting resistance factors, the presently described oligonucleotides may render an otherwise antibiotic resistant organism sensitive to conventional antibiotics. Accordingly, another embodiment of the present invention is the use of antibacterial oligonucleotides in conjunction with conventional antibiotics.

Another embodiment of the present invention involves the use of the presently described oligonucleotides to inhibit the expression of genes whose products regulate the replication or transfer of bacterial genes. Additionally, given that antibiotic resistance genes or other virulence factors are often encoded by plasmids, antibacterial oligonucleotides targeted against plasmid replication, transfer (by conjugative transfer), or gene expression are particularly of interest. Similarly, antibacterial oligonucleotides are contemplated that are capable of inhibiting the expression and transfer of genes encoded by transposable genetic elements (e.g., transposons).

4.4.1. Selection Of Targets For Oligonucleotides: Gene/Operon Target Identification

Antisense oligonucleotides which target essential structural genes, metabolic pathway genes, or transport system genes will inhibit the growth of bacterial cells. For pathogenic bacteria, virulence factors such as, for example, genes encoding antibiotic resistance, toxins, adherence and invasion factors, pili or fimbriae, flagella, antigenic variation factors, and iron binding factors, are also

preferred targets. These targets should be pathogen specific, and thus oligonucleotides directed against these targets will preferably not harm either host cells, or the normal bacterial flora of the gut.

- 5 While some bacterial genes are expressed as individual transcripts, many are transcribed as part of a multicistronic unit or operon. Examples include the ribosomal protein operons, such as the *str* operon and the alpha operon in *Escherichia coli*. Where possible operon transcripts are
- 10 targeted. Disruption of expression of a gene in the operon may also adversely effect the expression of other genes encoded within the same operon (often in operon transcripts the translation of the 5'-most genes are required for efficient translation of the downstream genes). In theory
- 15 this could result in pleiotropic growth effects from a single oligonucleotide sequence. Specific genes and transcripts (whether expressed as part of an operon or independently) are targeted on the basis of their function in the cell. For example, the gene for glucose-6-phosphate dehydrogenase is
- 20 central to sugar metabolism. Other genes may not be relevant in our normal assay system; disruption of lactose metabolism is expected to have only a minor effect, if any, on *Escherichia coli* growth in media containing a more readily available carbon source such as glucose.
- 25 Once a target gene or operon has been selected, a target region within the gene or operon sequence must be selected, for example, the start codon. An analysis of the sequences around the target sequence (e.g., 5' untranslated region, start codon, internal sequence feature, termination codon, 3'
- 30 untranslated region) is performed. This analysis generally encompasses a total of about 120 bases that flank the target sequence. This analysis further predicts the secondary structure of the antisense oligonucleotide, and can be performed using commercially available computer software.
- 35 The extended target sequence is checked for regions of stable secondary structure. The positions of the bases predicted to be involved in the stem-and-loop structures should be marked

and the predicted T_m of the structures noted. Preferably, stem sequences should be avoided where possible. Moreover, predicted secondary structures with predicted melting temperature of 45°C or less are disregarded in this analysis.

5 A maximum oligonucleotide length is also selected, and the program identifies the clear regions (no stems, or the structures with the lowest melting temperatures), and also checks the loop melting temperatures for the generated oligonucleotides. Such programs are well known in the art
10 and include, for example, the program *OligoTech* version 1.0 (Copyright© 1995, Oligos Etc. Inc. & Oligo Therapeutics Inc.).

The length of the flanking sequence to be analyzed may be increased if an oligonucleotide with a length of greater
15 than 30 bases is selected. The transcription start site and termination site (or any attenuation sequence) are generally the most distal sequences that will be analyzed. On occasion, this may result in an analysis of about 190 or more bases of flanking sequence.

20 Potential oligonucleotide sequences that have high loop melting temperatures may be eliminated by the above analysis. Note that the melting temperatures for the loops obtained for the commercial programs may need to be adjusted for modified oligonucleotides since these oligonucleotides may have
25 altered base pairing avidities.

Several additional characteristics of the oligonucleotides are also considered. Stable secondary structure (potentially stable under physiologic conditions), runs of a single base (e.g., 4 or more A's), and sequences
30 that potentially form stable homodimers are also eliminated if possible. (In cases where double-strand oligonucleotide is the desired end result, homodimers may be preferred.) The base composition of the oligonucleotide is also checked.

The two or three oligonucleotide sequences that most
35 nearly meet the above criteria are selected. Using these final oligonucleotides, the program analyzes each sequence and notes loop melting temperatures for both the sense and

the antisense strands of the candidate sequences. This decreases the possibility of the computer analysis missing a potential problem structure.

The candidate sequences, selected as above, are searched 5 for sequence matches in available sequence databases (for example, Genbank) using commercially available search software. The first search is against the bacterial sequence database(s). This allows the identification of other targets that may also be affected by the candidate sequence, and may 10 also indicate which sequences are potentially effective across bacterial genera. Since many different bacterial genera have highly related genetic organizations or related gene sequences, a potential oligonucleotide may be effective against multiple bacterial genera. For example, the 15 sequences of the *gyrA* genes of *Escherichia coli* and *Salmonella typhimurium* are essentially identical near the start codon.

Additionally, since bacterial translation occurs simultaneously with transcription, it may be generally 20 preferable to target antisense oligonucleotides to bacterial sequences at or near the Shine-Delgarno site (ribosome binding site) or to the translation start site of the targeted transcript.

The second search is versus a database including 25 human/primate sequences. Since these databases are still quite limited (relative to the entire amount of sequence data in the genome), databases generally including mammalian sequences should be searched. Oligonucleotides that have high specificity matches to relevant mammalian sequences 30 should be eliminated from initial consideration. (Note: that they may be re-included after further evaluation of the possible target sequences.)

As a consequence of the incomplete nature of the data bases comprising bacterial, primate, rodent, and mammalian 35 sequences, this method cannot ensure that all potential targets or conflicts are identified. However, as sequence data accumulates, this method will allow an experienced

practitioner of the art to identify targets and select oligonucleotide sequences for use in the methods of the invention.

5 4.5. Bacterial Inhibition Assay: MIC Test

Despite some limitations of *in vitro* susceptibility tests, the clinical data indicate that there is good correlation between MIC test results and *in vivo* efficacy of antibiotics. Murray, P., Antimicrobial Susceptibility Testing, (Poupard et al., eds.), Plenum Press, NY, 1994; Knudsen et al., *Antimicrob. Agents Chemother.* 39(6):1253-1258 (1995).

Accordingly, the presently described antibacterial oligonucleotides were tested for antibacterial activity in *in vitro*. Prior to use *in vivo*, a given antibacterial oligonucleotide will have demonstrated antibacterial activity *in vitro* against a pathogenic bacteria. Generally, the *in vitro* antibacterial activity of an oligonucleotide will be tested using a standard bacterial inhibition assay, or MIC test (see National Committee on Clinical Laboratory Standards "Performance Standards for Antimicrobial Susceptibility Testing" NCCLS Document M100-S5 Vol. 14, No. 16, December 1994, herein incorporated by reference).

25 4.5.1. Variations On The Standard MIC Test

Cells that are growing exponentially *in vitro* are generally not representative of cells in clinical infections where nutrients may be limited and the cells are dividing slowly or not at all, i.e., the cells are in stationary phase. Starved stationary phase cells undergo a series of morphological and physiological changes that distinguish them from cells in exponential growth. These changes ensure the prolonged survival of the cells by reducing endogenous metabolism and preparing the cells for possibly adverse conditions.

Further, there is a specific interrelation between the growth rate of bacterial cells and the sensitivity of the

cells to chemicals, antibiotics, and host defenses. Thus, antibiotics developed and tested against laboratory cultures are often ineffective when directed against relatively slowly growing, clinical infections.

5 In an effort to address the issue of bacteria growing under starved conditions in a clinical setting, both fresh cultures and starved cultures of bacteria were used as inocula in standard MIC tests. Oligonucleotides with antibacterial activity proved effective regardless of the
10 type of inoculum used in the MIC test.

The MIC is the lowest concentration of antimicrobial agent that completely inhibits growth of the organism in the tubes or microdilution wells as detected by the unaided eye. Viewing devices intended to facilitate reading microdilution
15 tests and recording of results may be used as long as there is no compromise in the ability to discern growth in the wells. The amount of growth in the wells or tubes containing the antibiotic should be compared with the amount of growth in the growth-control wells or tubes (no antibiotic) used in
20 each set of tests when determining the growth and points.

The percent inhibition of an oligonucleotide as reported herein was the absorbance at 625 nanometers of a bacterial culture that was treated with the oligonucleotide divided by the absorbance at 625 nanometers (i.e., O.D. 625) of a
25 duplicate cell culture minus oligonucleotide (control); the resulting number was subtracted from 1, and multiplied by 100%. Small variations in the optical density readings at the lower detection limit of the assay may result in calculated inhibitions of greater than 100 percent. It is
30 assumed that these calculations essentially represent 100 percent inhibition.

The concentration of target bacteria used in an MIC assay typically far exceeds the systemic concentrations of pathogenic bacteria that, with the possible exception of
35 abscesses, are expected to be found in vivo. While even the presence of a single bacterium in bodily fluids is considered an indication of infection (John J. Sherris, Editor, Medical

Microbiology, An Introduction to Infectious Diseases, 2nd Edition, Elsevier, New York 1990), the precise number of bacteria/ml is not well quantified in human clinical infections (Kjeldfberg and Knight (3rd Edition), Body Fluids, 5 ASCP Press, 1993). It is difficult to quantitate bacteria in body fluids as bacteria are constantly cleared by the immune system (Myrvik, Fundamentals of Medical Bacteriology, 1974, Lea & Febiger, Publishers). In addition, bacteria grow more slowly in vivo than in vitro, so this slow growth combined
10 with the clearance by the immune system makes quantifying the number of bacteria difficult. In order to quantitate clearance of *Pneumococci* in the blood, Wilson (G.S. Wilson and A.A. Miles, Editors, Topley and Wilson's Principles of Bacteriology and Immunology, Williams & Wilkins, Publishers,
15 1964) reported a study where bacteria were intravenously injected into rabbits. It is evident from these data that if the immune system is unable to clear the bacteria from the blood, once the concentration of bacteria reaches 1.5×10^6 cfu per ml the animal will die. In light of the above
20 discussion, the oligonucleotides need only arrest the growth of the bacteria until the immune system is capable of clearance. Furthermore, in an actual clinical situation, the concentration of bacteria/ml would be far lower than 1.5×10^6 /ml, which represents a fatal concentration in Wilson's
25 animal model.

In the presently described studies, the bacteria were grown over the period of the assays to an O.D. 600 of 0.1 as defined by the NCCLS. This represents approximately 1×10^8 concentration of bacteria which represents more bacteria/ml
30 than would be required to cause death in a clinical setting.

4.5.2. Fastidious Organisms

The standard media used in the MIC tests described above for the rapidly growing aerobic pathogens (Mueller-Hinton
35 medium) is not adequate for susceptibility testing of fastidious organisms. Where MIC tests are to be done using fastidious organisms, the medium, quality control procedures,

and interpretive criteria must be modified to fit each organism. For example, dilution tests for *Haemophilus influenzae* (using *Haemophilus* test medium), *Nisseria gonorrhoeae* (using GC agar base medium), and *Streptococcus pneumoniae* (using lysed horse blood-supplemented, cation-adjusted Mueller-Hinton broth) have been shown to be reliable methods. It is important to note that the direct inoculum suspension method of preparing the test inoculum must be used with these three species. The media and important technical aspects of testing several fastidious species are described in relevant sections above and outlined in NCCLS Doc. M7-A3, Vol. 13, No. 25, entitled "Methods for Dilution Antimicrobial Susceptibility Tests for Bacteria that Grow Aerobically - Third Edition; Approved Standard". Interpretive criteria for testing these three fastidious species can also be found in NCCLS Doc. M7-A3, Vol. 13, No. 25.

4.6. Antibacterial Activity In vivo

After demonstrating antibacterial activity *in vitro*, the antibacterial oligonucleotide will be tested for activity *in vivo*. In brief, an antibacterial oligonucleotide sequence (e.g., a phosphorothioate ODN) will be tested for antibiotic activity in a mammalian test subject, and preferably a murine test subject. Phosphorothioate ODNs have previously been tested in mammals (mice, rats, rhesus monkeys), and, when properly administered, have not been found to be significantly toxic. Prior to introduction *in vivo*, ODNs will be solubilized in sterile saline and serially-diluted to the desired test concentrations in sterile saline.

Bacteria. Bacterial pathogens to be used *in vivo* include, but are not limited to, *inter alia*, the drug-resistant *Escherichia coli* ATCC accession No. 25922, and *Staph. aureus* ATCC accession No. 13301. Generally, the target/test bacteria are cultured *in vitro* in Mueller-Hinton broth (BBL Microbiology Systems, Cockeysville, MD) for 18 hours at 37°C.

Typically, cultures of a test pathogen will be prepared by suspending colonies grown on solid medium (for example, trypticase soy agar plates) into 70 ml of Mueller-Hinton broth so that a culture with an optical density of about 0.1 at 540 nm results. Appropriate dilutions of the bacterial cells are then prepared in DPBS.

Animals. Typically, any acceptable animal model may be used to assess the efficacy of the antibacterial oligonucleotides. Additionally, experimental protocols and conditions will necessarily be adjusted as applicable depending on the bacterial pathogen being tested and the mode of infection. Accordingly, the following example is provided merely for purposes of exemplification and should not be deemed as limiting the present invention in any way whatsoever.

Six- to eight-week-old CD1 mice or NMRI mice, 24-28 g in size, are typically used in these studies. The CD1 strain of mouse has been used in the past for certain studies of infectious diseases and therapeutics (e.g., Brogden et al., (1986); Cavalieri et al., (1991); Lister and Sanders, Antimicrob. Agents Chemother. 39:930-936 (1995)), as has the NMRI strain (Hof et al., Infection 14:190-194 (1986)). Thus, both of the above strains are exemplary of well established infectious disease models that are also readily available to those of ordinary skill.

Typical animal tests comprise a minimum of about 5-8 animals in each treatment group (1 cage of 5 mice each) in order to demonstrate adequately the statistical reproducibility of a given experimental observation. By using at least about 5 test animals, one can compensate for variabilities such as differing growth rates of microorganisms in a given animal and any variables introduced by the repeated handling and injection of the animals.

Injection of microorganisms. Test animals are typically injected subcutaneously (SC) on the back (intrascapular) with approximately 0.3 ml of bacterial cell suspension in 1.5% liquified sterile tryptose phosphate agar held at 39°C

essentially as described by Hof et al. (1986) or I.P. with 5% mucin (Lister & Sanders, 1995).

Administration of Oligonucleotides. At the time of injection of bacteria or at various times after injection with the indicated microorganism, the test animals are treated by administration of a bolus injection of oligonucleotides at, for example, 0, 1.0, 2.5, 5.0 or 10.0 mg/kg (5 separate groups, one dose per group of 12 animals) to determine optimum therapeutic dose of a given antibacterial oligonucleotide. The oligonucleotide is generally administered I.P. in a volume of approximately 0.5 ml of sterile saline, using a sterile 25-gauge needle or through an Alzets pump. Optionally, the solution comprising the antibacterial oligonucleotide may also be administered I.V., subcutaneously, orally, or by any other means suitable for the given pathogen being tested.

Where applicable, bacteremia will be monitored by collecting daily blood samples from two animals from each group. One fully-anesthetized animal from the negative control group (no bacterial infection) will be bled by cardiac puncture and subsequently euthanized. The number of colony forming units (CFU) in the blood samples will then be determined by plating samples on agar and doing bacterial colony assays.

The minimum lethal dose for a given bacterial pathogen, e.g., *Escherichia coli* ATCC accession No. 25922, is determined for CFI mice after the pathogen is injected I.P. in 0.5 ml DPBS or S.C. plus agar. The minimum lethal inoculum is the minimum dose that results in the death of all of the test subjects during the five to seven days post-infection.

Alternatively, female NMRJ mice may be used with, for example, *Escherichia coli* ATCC accession No. 25922, which is known to cause animal death within five to seven days after intra-clavicular injection.

The dose of antibacterial oligonucleotide that protects 50% of the test animals from death (protective doses 50%-PD₅₀)

is determined as follows. Beginning at various times after injection of the bacterium into the test animals, and continuing for four days thereafter, the antibacterial oligonucleotide (or its control) is injected S.C. into the 5 test animals in about 0.15 ml DPBS at final concentrations that will vary as appropriate for the given assay. For example, about 0.0, 1.0, 2.0, 2.5, and 5.0 mg/kg of antibacterial oligonucleotide may typically be used. Animals surviving for more than five to seven days after initial 10 bacterial inoculation will be maintained an additional seven days, and then euthanized by CO₂ asphyxiation for further study. Optionally, the test animals are maintained for more extended periods after initial infection in order to assess the long-term efficacy of oligonucleotide treatment.

15 A similar bacterial inoculation and oligonucleotide treatment protocol can be used to determine the kinetics of bacteria clearance from the peripheral blood of bacteremic animals after treatment with antibacterial oligonucleotide. In these studies, groups of twelve animals each are infected 20 as above with *Escherichia coli*, and a group of six mice is sham injected with only saline (the control group). The groups of infected mice are then treated with (a) saline or (b) oligonucleotide, while the control group is only treated with saline. At suitable time periods post-infection, blood 25 samples are taken, and the number of test pathogen cells per ml of blood is determined by standard dilution and culture methods.

The above animal models are merely exemplary of the myriad of animal models that may be used to establish the 30 efficacy of the presently described antibacterial oligonucleotides, and many other modalities for testing the claimed invention are available to one of ordinary skill. For example, the LD₅₀ of a given pathogen may be established (or previously known), and the efficacy of the antibacterial 35 oligonucleotide determined, testing whether substantially all of the test animals survive bacterial exposure.

Additionally, immunocompromised animals may also be used, i.e., nude mice, SCID mice, etc., to study the antibacterial effects of the described oligonucleotides in the absence of a correctly functioning immune system.

5

4.7. Pharmaceutical Compositions And Delivery

Pharmaceutical compositions containing the oligonucleotides of the invention in intimate admixture with a pharmaceutical carrier can be prepared according to
10 conventional pharmaceutical compounding techniques. The carrier may take a wide variety of forms depending on the form of preparation desired for administration, e.g., intravenous, oral, topical, aerosol (for topical or inhalation therapy), suppository, parenteral, or spinal
15 injection.

In preparing the compositions in oral dosage form, any of the usual pharmaceutical media may be employed, such as, for example, water, glycols, oils, alcohols, flavoring agents, preservatives, coloring agents and the like in the
20 case of oral liquid preparations (such as, for example, suspensions, elixirs, and solutions); or carriers such as starches, sugars, diluents, granulating agents, lubricants, binders, disintegrating agents and the like in the case of oral solid preparations (such as, for example, powders,
25 capsules and tablets). Because of their ease in administration, tablets and capsules represent the most advantageous oral dosage unit form, in which case solid pharmaceutical carriers are obviously employed. If desired, tablets may be sugar-coated or enteric-coated by standard
30 techniques. Oral dosage forms of antibacterial oligonucleotides will be particularly useful for the treatment of bacterial infections of the gastrointestinal tract and ulcers caused by or associated with bacterial infection (e.g., *Helicobacter pylori* infection, and the
35 like). Additionally, given that bacterial infection has been associated with hyperproliferative disorders of the immune system (i.e. inflammatory bowel disease), the presently

described antibacterial oligonucleotides may be used to treat hyperproliferative disorders including, but not limited to, Crohn's disease and ulcerative colitis by specifically eliminating the causative or contributory microorganisms from
5 the bacterial flora of the gut.

For parenteral application by injection, preparations may comprise an aqueous solution of a water soluble, or solubilized, and pharmaceutically acceptable form of the antibacterial oligonucleotide in an appropriately buffered
10 saline solution. Injectable suspensions may also be prepared using appropriate liquid carriers, suspending agents, pH adjusting agents, isotonicity adjusting agents, preserving agents, and the like may be employed. Actual methods for preparing parenterally administrable compositions and
15 adjustments necessary for administration to subjects will be known or apparent to those skilled in the art and are described in more detail in, for example, Remington's Pharmaceutical Science, 15th Ed., Mack Publishing Company, Easton, Pa (1980), which is incorporated herein by reference.
20 The presently described oligonucleotides should be parenterally administered at concentrations below the maximal tolerable dose (MTD) established for the antibacterial oligonucleotide.

For topical administration, the carrier may take a wide
25 variety of forms depending on the preparation, which may be a cream, dressing, gel, lotion, ointment, or liquid.

Aerosols are prepared by dissolving or suspending the oligonucleotide in a propellant such as ethyl alcohol or in propellant and solvent phases. The pharmaceutical
30 compositions for topical or aerosol form will generally contain from about 0.01% by weight (of the oligonucleotide) to about 40% by weight, preferably about 0.02% to about 10% by weight, and more preferably about 0.05% to about 5% by weight depending on the particular form employed.

35 Suppositories are prepared by mixing the oligonucleotide with a lipid vehicle such as theobroma oil, cacao butter, glycerin, gelatin, or polyoxyethylene glycols.

The presently described antibacterial oligonucleotides may be administered to the body by virtually any means used to administer conventional antibiotics. A variety of delivery systems are well known in the art for delivering 5 bioactive compounds to bacteria in an animal. These systems include, but are not limited to, intravenous or intramuscular or intrathecal injection, nasal spray, aerosols for inhalation, and oral or suppository administration. The specific delivery system used depends on the location of the 10 bacteria, and it is well within the skill of one in the art to determine the location of the bacteria and to select an appropriate delivery system.

The present invention is further illustrated by the following examples, which are not intended to be limiting in 15 any way whatsoever.

5.0. EXAMPLES

5.1. Oligonucleotide Synthesis

Oligonucleotides were synthesized using commercial 20 phosphoramidites on commercially purchased DNA synthesizers at either 1 μ M or 15 μ M scales using standard phosphoramidite chemistry. Oligonucleotides were deprotected following phosphoramidite manufacturers protocols. Oligonucleotides to be used unpurified were either dried down under vacuum or 25 precipitated and then dried.

Sodium salts of oligonucleotides were prepared using the commercially available DNA-Mate (Barrskogen, Inc.) reagents or conventional techniques such as the commercially available exchange resin, e.g., Dowex (Tradename), or by addition of 30 sodium salts followed by precipitation, diafiltration, or gel filtration, etc.

Oligonucleotide preparations that would be subject to further purification were initially chromatographed on commercially available reverse phase or ion exchange media 35 (preferably, SAX, strong anion exchange media) such as Source Q made by Pharmacia, Toyopearl super Q made by Tosohaas, Protein Pak made by Waters, Macrorep Q made by BioRad, and

the like. Peak fractions were combined and the samples desalted and concentrated by ethanol precipitation, diafiltration, or gel filtration followed by lyophilization or solvent evaporation under vacuum in commercially available instrumentation such as Savant's Speed Vac. Optionally, the oligonucleotides may also be electrophoretically purified using polyacrylamide gels.

A variety of commercially available gel filtration media are particularly well suited for the desalting and/or purification of antibacterial oligonucleotides. Gel filtration media which may be used include Sephadex or Superdex made by Pharmacia, Trisacryl made by BioSeptra, BioGel (preferably P-series, or more preferably P4) made by BioRad, Toyopearl HW SEC made by Tosohaas, Cellufine made by Amicon, and the like. Optionally, the gel filtration step may be repeated several times in order to better remove low molecular weight species, and particularly alkyl amines and/or alkyl ammonium compounds, from the oligonucleotide preparations.

Cation exchange columns comprising media such as Macrorep S (or CM) made by BioRad (preferably in the NH_4^+ form), Dowex resins, or Amberlite resins are also useful to remove contaminants from antibacterial oligonucleotide preparations. Typically, the pH of the eluted oligonucleotide will be increased to about 7-8 using ammonium hydroxide consequential to this step.

Alternatively, exhaustive dialysis or diafiltration may be used to remove salts or contaminants that inhibit or mask the antibacterial activity of the oligonucleotides (e.g., alkyl amines and/or alkyl ammonium compounds). Exhaustive butanol extractions, chloroform extraction followed by ethanol washes or multiple ethanol extractions may be used to obtain purified oligonucleotides that retain antibacterial activity.

Oligonucleotides to be used in bacterial experiments were dissolved in pyrogen free, sterile, physiological saline (i.e., 0.85% saline), sterile Sigma H_2O , and filtered through

a 0.45 micron Gelman filter (or a sterile 0.2 micron pyrogen free filter prior to animal studies). Table 1 contains a list of all oligonucleotide sequences used in the examples. Although the majority of oligonucleotides used in the

5 examples were constructed using a phosphorothioate backbone, unless otherwise noted, it should be understood that any of a wide variety of chemical backbones could be also used to generate oligonucleotides comprising the sequences listed in Table 1. The antibacterial oligonucleotides were tested

10 for inhibition (INH) activity against drug resistant Gram negative (*Escherichia coli* ATCC accession No. 35218) and Gram positive (*Staphylococcus aureus* ATCC accession No. 13301) microorganisms. The percent inhibition data in Table 1 were averaged and normalized to a concentration of 2 mg/ml.

15 Tables 2 (A-W) provide time course experiments that test the inhibitory activity (against *Escherichia coli* ATCC accession No. 35218 or *Staphylococcus aureus* ATCC accession No. 13301) of the indicated oligonucleotides when present at 2 mg/ml in the culture medium as targeted against genes that

20 represent nearly all known gene classes in bacteria. In brief, Table 2A shows the inhibitory effect of oligonucleotide 28 (NBT 28, SEQ ID NO. 1); Table 2B tests oligonucleotide 10 (SEQ ID NO. 17); Table 2C tests oligonucleotide 43 (SEQ ID NO. 34), Table 2D shows the

25 inhibitory effect of oligonucleotide 27 (SEQ ID NO. 45); Table 2E tests oligonucleotide 2 (SEQ ID NO. 120); Table 2F tests oligonucleotide 89 (SEQ ID NO. 61); Table 2G tests oligonucleotide 103 (SEQ ID NO. 64); Table 2H tests oligonucleotide 132 (SEQ ID NO. 65), Table 2I shows the

30 inhibitory effect of oligonucleotide 19 (SEQ ID NO. 66); Table 2J tests oligonucleotide 16 (SEQ ID NO. 72); Table 2K tests oligonucleotide 96 (SEQ ID NO. 79); Table 2L tests oligonucleotide 21 (SEQ ID NO. 85); Table 2M shows the inhibitory effect of oligonucleotide 18 (SEQ ID NO. 95);

35 Table 2N tests oligonucleotide 105 (SEQ ID NO. 103); Table 2O tests oligonucleotide 46 (SEQ ID NO. 105); Table 2P tests oligonucleotide 114 (SEQ ID NO. 112); Table 2Q tests

oligonucleotide 32 (SEQ ID NO. 116); Table 2R tests oligonucleotide 73 (SEQ ID NO. 124); Table 2S tests oligonucleotide 63 (SEQ ID NO. 130), Table 2T shows the inhibitory effect of oligonucleotide 78 (SEQ ID NO. 134);
5 Table 2U tests oligonucleotide 71 (SEQ ID NO. 151); Table 2V tests oligonucleotide 14 (SEQ ID NO. 154); and Table 2W tests oligonucleotide 5 (SEQ ID NO. 152).

5.2. MIC With *Escherichia coli*

10 Oligonucleotides from every known gene class in bacteria were used to test inhibition of bacterial growth in a modified MIC test (described above). In all cases the control bacterial cells entered exponential growth while the test cells to which oligonucleotide had been added showed no
15 growth at all or significant inhibition of growth (see Table 1).

Similar results were achieved with other oligonucleotides selected using the parameters described above, which were subsequently synthesized, purified and
20 tested using the same MIC analysis. See Table 1.

The results in Table 1 demonstrate that antisense or antigene (inhibition of expression by DNA triplex formation) oligonucleotides are effective against a variety of genes. For example: genes involved in energy metabolism (sugar
25 metabolism, fatty acid metabolism), cell division (DNA replication, cell wall biosynthesis), global regulatory proteins, protein synthesis (tRNA synthesis, mRNA stability, rRNA synthesis, ribosomal protein, translation factors), virulence factors, cell wall and membrane synthesis (fatty
30 acid and phospholipid synthesis, lipopolysaccharide synthesis, periplasmic-secretory proteins, transport proteins, outer-membrane proteins), amino acid biosynthesis, nucleic acid synthesis, nitrate reductase, vitamin metabolism, and drug resistance.

35 In fact, Figure 2 shows that the described antibacterial oligonucleotides proved effective against a wide variety of genes from both Gram negative and Gram positive bacteria.

More specifically, oligonucleotides targeted against bacterial genes relating to: energy metabolism (A); DNA replication (B); cell division (C); regulatory proteins (D); cell wall biosynthesis (E); sugar metabolism (F); virulence, 5 pili, flagella (G); fatty acid metabolism (H); mRNA synthesis (I); tRNA synthesis (J); rRNA synthesis (K); ribosomal protein synthesis (L); protein synthesis (M); phospholipid synthesis (N); periplasmic/secretory protein synthesis (O); regulation and synthesis of transport proteins (P); amino 10 acid biosynthesis and metabolism (Q); lipopolysaccharide synthesis (R); purine/pyrimidine biosynthesis and metabolism (S); outer membrane protein synthesis and regulation (T); nitrate reductase synthesis and regulation (U); drug resistance (V); and vitamin metabolism and biosynthesis (W) 15 were capable of significantly inhibiting the growth of both Gram negative and Gram positive bacteria.

Thus, antibacterial oligonucleotides were effective against virtually every major cellular function tested (as determined by the MIC assay).

20 As additional genome sequence data are obtained for bacteria, this invention may be extended to oligonucleotide targets within newly described bacterial sequences. Antibacterial oligonucleotides may be constructed with a range of backbones including, but not limited to: 25 phosphorothioates; p-ethoxy oligonucleotides (partially or fully substituted); or 2'-O-methyl oligonucleotides (partially or fully substituted). Oligonucleotides comprising all of the above backbones have proved equally effective in inhibiting bacterial growth. In view of the 30 effectiveness of oligonucleotides comprising the chemical backbones listed above, chimeric oligonucleotides (comprising mixed backbones) are also deemed to be effective antibacterial agents.

Several oligonucleotides based on the NBT 18 sequence 35 (SEQ ID NO. 95) were also capable of inhibiting the growth of two clinically relevant pathogens that have proven resistant to most conventional antibiotics - *Escherichia coli* clinical

isolate ATCC accession No. 35218 (Tables 3A and 3B), and *Staphylococcus aureus* clinical isolate ATCC accession No. 13301 (Tables 3C and 3D). The NBT 18 sequence variations that were tested in Tables 3A and 3B include: A - the NBT 18 sequence with a 2'-O-Methoxy substituted backbone; B - a truncated (12mer, SEQ ID NO. 174) version of the NBT 18 sequence with a phosphorothioate backbone; C - a truncated (15mer, SEQ ID NO. 175) region of the NBT 18 sequence with a phosphorothioate backbone; D - a truncated (15mer) region of the NBT 18 sequence with a phosphorothioate backbone and a 5' amino group; and E - the NBT 18 sequence with a phosphorothioate backbone. The NBT 18 sequence variations that were tested in Tables 3C and 3D include: A - the NBT 18 sequence with a 2'-O-Methoxy substituted backbone; B - the NBT 18 sequence with a p-ethoxy substituted backbone; C - a truncated (12mer) region of the NBT 18 sequence with a phosphorothioate backbone; D - a truncated (15mer) region of the NBT 18 sequence with a phosphorothioate backbone; and E - a truncated (18mer, SEQ ID NO. 176) region of the NBT 18 sequence with a phosphorothioate backbone. The data in Tables 3(A-D) indicate that the observed antibacterial effect was largely a feature of the antisense sequence of NBT 18 instead of the backbone of a given oligonucleotide (i.e., nonspecific sulphur effects, etc.).

These data further indicate that oligonucleotides comprising less than one half of the full-length (27 base) sequence of NBT 18 retain the ability to inhibit the growth of at least two clinically significant pathogens.

5.3. MIC With Gram Negative And Gram Positive Bacteria

A representative number of the antisense oligonucleotides were tested against a wide variety of bacterial species including *Streptococcus* (*Streptococcus mutans* (ATCC accession No. 25175)), *Streptococcus pyogenes* (ATCC accession No. 14289), *Streptococcus pneumoniae* or *Pneumococcus pneumoniae* (ATCC accession No. 39937), and *Streptococcus faecalis* or *Enterococcus faecalis* (ATCC

accession No. 19433), *Staphylococcus aureus* (ATCC accession No. 29213), *Staphylococcus aureus* (ATCC accession No. 13301), *Escherichia coli* (ATCC accession Nos. 11370, 25922, and 29214), *Salmonella typhimurium* (ATCC accession No. 23564),
5 *Pseudomonas fluorescens* (ATCC accession No. 13525), *Klebsiella pneumoniae* (ATCC accession No. 4352), *Serratia liquefaciens* (ATCC accession No. 27592), *Neisseria sicca* (ATCC accession No. 9913), *Mycobacterium smegmatis* (ATCC accession No. 19420), *Yersinia mollareti* (ATCC accession No.
10 43969), *Haemophilus segnis* (ATCC accession No. 33393), *Haemophilus vaginalis* (ATCC accession No. 14018), *Shigella* sp. (ATCC accession No. 11126), *Vibrio fischeri* (ATCC accession No. 7744), and *Helicobacter mustelae* (ATCC accession No. 43772).

15 Representative data generated with phosphorothioate forms of the oligonucleotides are provided in Tables 4(A-Z). In brief, antibacterial oligonucleotides nos. 18 (SEQ ID NO. 73), 39 (SEQ ID NO. 30), 63 (SEQ ID NO. 130), 78 (SEQ ID NO. 134), and 73 (SEQ ID NO. 124) were tested against *Salmonella*
20 *typhimurium* (Tables 4A and 4B); antibacterial oligonucleotides 39 (SEQ ID NO. 30), 63 (SEQ ID NO. 130), 78 (SEQ ID NO. 134), 82 (SEQ ID NO. 161), and 114 (SEQ ID NO. 112) were tested against *Pseudomonas aeruginosa* (Tables 4C and 4D); antibacterial oligonucleotides 114 (SEQ ID NO. 112),
25 78 (SEQ ID NO. 134), 73 (SEQ ID NO. 124), 71 (SEQ ID NO. 151), and 111 (SEQ ID NO. 132) were tested against *Klebsiella pneumoniae* (Tables 4E and 4F); antibacterial oligonucleotides 2 (SEQ ID NO. 50), 4 (SEQ ID NO. 173), 127 (SEQ ID NO. 143), 63 (SEQ ID NO. 130), and 73 (SEQ ID NO. 124) were tested
30 against *Yersinia mollaretti* (Tables 4G and 4H); antibacterial oligonucleotides 16 (SEQ ID NO. 72), 12 (SEQ ID NO. 80), 20 (SEQ ID NO. 84), 3 (SEQ ID NO. 121), and 15 (SEQ ID NO. 81) were tested against *Neisseria sicca* (Tables 4I and 4J); antibacterial oligonucleotides 2 (SEQ ID NO. 50), 39 (SEQ ID
35 NO. 30), 82 (SEQ ID NO. 161), and 114 (SEQ ID NO. 112) were tested against *Serratia liquefaciens* (Table 4K); antibacterial oligonucleotides 1 (SEQ ID NO. 119), 89 (SEQ ID

NO. 61), 127 (SEQ ID NO. 143), 132 (SEQ ID NO. 15), and 114 (SEQ ID NO. 112) were tested against *Streptococcus mutans* (Tables 4L and 4M); antibacterial oligonucleotides 1 (SEQ ID NO. 119), 89 (SEQ ID NO. 61), 127 (SEQ ID NO. 143), 132 (SEQ ID NO. 15), and 114 (SEQ ID NO. 112) were tested against *Streptococcus pyogenes* (Tables 4N and 4O); antibacterial oligonucleotides 1 (SEQ ID NO. 119), 89 (SEQ ID NO. 61), 127 (SEQ ID NO. 143), 132 (SEQ ID NO. 15), and 114 (SEQ ID NO. 112) were tested against *Shigella* (Tables 4P and 4Q);
10 antibacterial oligonucleotide 78 (SEQ ID NO. 134) was tested against *Haemophilus* (Table 4R); antibacterial oligonucleotides 114 (SEQ ID NO. 112), 10 (SEQ ID NO. 17), 21 (SEQ ID NO. 85), 18 (SEQ ID NO. 73), and 78 (SEQ ID NO. 134) were tested against *Mycobacterium* (Tables 4S and 4T);
15 antibacterial oligonucleotide 78 (SEQ ID NO. 134) was tested against *Helicobacter* (Table 4U); antibacterial oligonucleotides 89 (SEQ ID NO. 61), 127 (SEQ ID NO. 143), 132 (SEQ ID NO. 15), p127 (SEQ ID NO. 143 with a p-Ethoxy backbone), 1 (SEQ ID NO. 119), and 76 (SEQ ID NO. 127) were
20 tested against *Enterococcus* (Tables 4V and 4W); antibacterial oligonucleotides 1 (SEQ ID NO. 119), 78 (SEQ ID NO. 134), 114 (SEQ ID NO. 112), 127 (SEQ ID NO. 143), and 132 (SEQ ID NO. 15) were tested against *Streptococcus pneumonia* (Tables 4X and 4Y); and antibacterial oligonucleotides 78 (SEQ ID NO. 134) and 127 (SEQ ID NO. 143) were tested against *Vibrio* (Table 4Z). The data in Tables 4A-Z indicate that the antibacterial oligonucleotides targeted to varying classes of genes are capable of strongly inhibiting the growth of a broad spectrum of bacterial species. No significant
25 difference in antibacterial activity was found when different stereoisomers of phosphorothioate backbone oligonucleotides were tested.

Additionally, Figures 3(a-c) respectively provide time course data providing percent inhibition as a function of
35 time for oligonucleotides 73 (SEQ ID NO. 124), 63 (SEQ ID NO. 130), and 18 (SEQ ID NO. 73) as measured against *Salmonella typhimurium*; Figures 4(a-c) respectively provide time course

data showing percent inhibition as a function of time for oligonucleotides 39 (SEQ ID NO. 30), 78 (SEQ ID NO. 134), and 63 (SEQ ID NO. 130) as measured against *Pseudomonas aeruginosa*; and Figures 5(a-b) respectively provide time course data showing percent inhibition as a function of time for oligonucleotides 73 (SEQ ID NO. 124) and 114 (SEQ ID NO. 112) as measured against *Klebsiella pneumoniae*.

In view of the wide range of bacteria already successfully tested, any oligonucleotides chosen and prepared in the manner described herein will be equally effective against a given bacterial target. In addition to the species explicitly mentioned herein, a wide variety of other bacterial pathogens may be treated using the described compositions. A relatively comprehensive review of such pathogens is provided, *inter alia*, in Mandell et al., 1990, Principles and Practice of Infectious Disease 3rd. ed., Churchill Livingstone Inc., New York, N.Y. 10036, herein incorporated by reference.

20 5.4. MIC At 24 Hours

In order to distinguish whether the antibacterial oligonucleotides had transient bacteriostatic effects, or long lasting effects, MIC assays were extended to include a time point of over 24 hours. These data are presented in Tables 5A-D. Tables 5A and 5B show, *inter alia*, that oligonucleotides 21 (SEQ ID NO. 156), 68 (SEQ ID NO. 148), and 85 (SEQ ID NO. 106), 112 (SEQ ID NO. 62), and 18 (SEQ ID NO. 73) continue to substantially inhibit the growth of *Staphylococcus aureus* ATCC accession No. 13301, for at least 25 hours. These data indicate that the tested oligonucleotides have long-term bacteriostatic or bactericidal (see Figure 9, below) effects on *Staphylococcus aureus* ATCC accession No. 13301. Moreover, the timing of antibacterial oligonucleotide addition does not significantly affect the observed antibacterial activity since activity was seen when the addition of antibacterial oligonucleotide was delayed for 180, 350, or 480 min.

Conversely, Tables 5C-D indicates that, although a substantial amount of growth inhibition occurs initially, the same oligonucleotides do not significantly inhibit the growth of *Escherichia coli* ATCC accession No. 35218 when growth was assayed 27 hours after the bacteria were initially exposed to the oligonucleotides. The data in Tables 5C and 5D indicate that oligonucleotides 21 (SEQ ID NO. 156), 68 (SEQ ID NO. 148), 85 (SEQ ID NO. 106), 112 (SEQ ID NO. 62), and 18 (SEQ ID NO. 73) are bacteriostatic for *Escherichia coli* ATCC accession No. 35218. *Escherichia coli* ATCC accession No. 35218 represents a particularly virulent, multiple drug resistant strain of *Escherichia coli*. When oligonucleotide number 89 (SEQ ID NO. 61) was tested against *Escherichia coli* accession No. 25922, a moderately penicillin resistant strain, a dose-dependent long lasting bacteriostatic effect was observed (see Tables 5E and 5F). It is expected that multiple doses of the same oligonucleotide, rather than a single dose, might result in enhanced long-term activity against the more resistant *Escherichia coli* ATCC accession No. 35218.

The 24-hour MIC studies were performed essentially as described above with the exceptions that: growth of the target bacteria to reach an OD_{525} of 0.1 occurs in approximately 8 hours instead of about 12 to 16 hours; bacterial growth is monitored throughout the experiment as well as at the end-points; and an additional test was conducted that used starved cells as the initial inoculum instead of fresh log cultures (which provided similar antibacterial results).

5.5. Purification Studies

The MIC test was carried out as described in Section 4.5., *supra*. The test oligonucleotides received various post-synthesis treatments, and the percent inhibition of the cell culture growth was calculated as described *supra*. See Tables 6A and 6B.

Oligonucleotide NBT 78 (SEQ ID NO. 134), was given the following treatments:

- A. butanol precipitated and resuspended as an ammonium salt;
- 5 B. butanol precipitated, converted to a sodium salt, desalted on a gel filtration column (described Section 5.1);
- C. purified via anion exchange HPLC, desalted by gel filtration;
- 10 D. butanol precipitated, converted to a sodium salt, desalted on a reverse phase HPLC column (trityl off);
- E. butanol precipitated, ammonium hydroxide added, desalted via gel filtration, left as an ammonium salt;
- 15 F. butanol precipitated once, filtered through a 0.45 micron filter (e.g., Gelman Acrodisc, Millipore, Nalgene, etc.) followed by ethanol precipitation;
- G. butanol precipitated twice, filtered through a 0.45 micron filter (e.g., Gelman Acrodisc, Millipore, Nalgene, etc.), and washed three times with 95% ethanol;
- 20 H. butanol precipitated twice, filtered through a 0.45 micron filter (e.g., Gelman Acrodisc, Millipore, Nalgene, etc.), washed with chloroform and ethanol;
- 25 I. butanol precipitated twice, filtered through a 0.45 micron filter (e.g., Gelman Acrodisc, Millipore, Nalgene, etc.), butanol precipitated 2 more times, and washed once with ethanol.

30 The results in Tables 6A and 6B demonstrate that the protocol used to purify the oligonucleotides greatly affects bacterial susceptibility in a MIC test. Oligonucleotides that are treated only by butanol precipitation inhibited bacterial growth by less than 25 percent. However,
35 oligonucleotides that were subject to: a) gel filtration; b) four butanol precipitations; or c) two butanol extractions, followed by ethanol or chloroform extractions all

demonstrated greater than 85% inhibition of the growth of the test bacteria used in the MIC assay (see B, C, E, G, H and I). Oligonucleotides may also be purified by strong anion exchange (SAX) chromatography, reverse-phase chromatography, 5 strong cation exchange (SCX) chromatography, followed by size exclusion chromatography (SEC). Alternatively, after the first SCX column, a second SCX column can be run followed by a reverse-phase chromatography step. Optionally, the SCX step may be supplemented or replaced by an alcohol (e.g., 10 ethanol, etc.) precipitation step.

The above results demonstrated that proper post synthesis handling protocols play an integral role in the production of oligonucleotides that display antibacterial activity.

15 There are a variety of contaminants that may be present in an oligonucleotide preparation after cleavage from the solid supports and removal of the protecting groups, and even after HPLC treatment. These contaminants include residual protecting groups, and contaminants that are introduced or 20 generated during synthesis or purification. Examples of such contaminant include, but are not limited to, quaternary amines (particularly alkyl amines and/or alkyl ammonium compounds), acetamide, acetic acid, 2-cyanoethanol, isobutyramide, isobutyric acid, benzamide, benzoic acid, 25 succinimide, succinic acid, t-butylphenoxyacetamide (or acetic acid), phenoxyacetamide (or acetic acid). Given the results shown in Tables 6A and 6B, it is clear that the substantial removal of the above or other contaminants greatly enhances the antibacterial activity of an 30 oligonucleotide.

Contaminants that are particularly important to remove from the oligonucleotide preparations include compounds that directly or indirectly inhibit bacterial uptake of the oligonucleotides, or otherwise mask the antibacterial effects 35 of the oligonucleotides. One way that a contaminant may mask the antibacterial efficacy of an oligonucleotide is by stimulating bacterial growth in a manner that effectively

compensates for the antibacterial activity of a given oligonucleotide. Accordingly, the present finding that certain contaminants (i.e., alkyl amines and/or alkyl ammonium compounds) that are typically present in

5 conventional oligonucleotide preparations may mask the *in vitro* antibacterial activity of oligonucleotides represents a seminal discovery that requires a fundamental reassessment of the utility of oligonucleotides as antibacterial agents *in vivo*.

10 In particular, an impurity in anion exchange (AX) HPLC-purified modified linkage oligonucleotides has been isolated and partially characterized which stimulates bacterial growth both *in vitro* and *in vivo*. This impurity/stimulatory material is a mixture of small, polar, multialkyl amino or
15 alkyl ammonium compounds that have negligible absorbance at 254 nm. The impurity is apparently generated from the AX-HPLC stationary phase during the elution gradient.

The absence of an active chromophore at 254 nm effectively renders the impurity invisible to the absorbance
20 detectors used during HPLC of DNA oligonucleotides. Since anion exchange chromatography precludes the use of conductivity detectors to monitor peaks, the impurity is also virtually invisible during the purification and analytical HPLC procedures typically used in the manufacture of
25 oligonucleotides.

As shown above, the impurity can be removed and isolated from the oligonucleotide preparations by using a series of desalting steps. For example, in the first step, the oligonucleotide was concentrated by first loading the pooled
30 fractions of an AX purification run onto appropriately sized Hamilton PRP-1 or PRP-3 columns. The salt was then removed from the column by washing with water until the conductivity of the wash eluant was below 25 $\mu\text{S}/\text{cm}$. Finally, the oligonucleotide was eluted as a concentrated solution (app.
35 100-300 OD's per mL) using a moderately steep (5% per minute) gradient of water:90% ethanol. It should also be noted that oligonucleotides purified in this manner must contain at

least two phosphorothioate or p-ethoxy linkages, or some other non-polar modification in order to adequately absorb to the stationary phase.

In the second step, the oligonucleotide solution was concentrated or removed entirely by lyophilization prior to further purification by size-exclusion chromatography (SEC). The oligonucleotide was re-suspended in a minimum amount of water prior to application to the SEC column. Since essentially all of the salt from the AX purification was removed by the RP step, the oligonucleotide was dissolved in a relatively small volume of water. This small volume helps maximize resolution in the SEC step.

A column was prepared using virgin BioGel P-4 medium or fine particle SEC medium, using a modified manufacturer's procedure to swell the medium. The column used was 45-50 cm long and 2.2 cm diameter. The flow rate was approximately 1-2 mL/minute. This size column can be used to purify 1,000-3,000 OD's of modified linkage oligonucleotides that are at least 12 bases in length. If the oligonucleotides have more than 30% phosphorothioate linkages, the maximum loading drops to about 2,000 OD's. Columns and sample sizes may be scaled up as long as a flow velocity of about 30-75 cm/hr is maintained, and the column height remains at least about 40 cm.

The oligonucleotides were eluted with water while monitoring the conductivity and the absorbance at 254 nm. The purification may be easily be modified by monitoring at 280 nm, and the like. Collection began when the oligonucleotide concentration became appreciable (as measured by O.D.), and stopped at no later than about 8 minutes after collection began. If, after the conductivity initially rose, it fell and then began to rise again, collection was terminated. It was important to stop collection as described because oligonucleotides collected after this point typically included the stimulatory impurities.

The collected oligonucleotide solutions were checked for concentration and lyophilized. Typically, the above protocol

resulted in the purified oligonucleotides having the desired antimicrobial activities.

When separation continued after the collection of the oligonucleotide peak, several other peaks were seen which displayed little to no absorbance at 254 nm, but noticeable conductivity. The amount of impurity observed varied for each individual purification. The variation was probably attributable to the different salt concentrations required to elute different oligonucleotides, or variations in the length of time since the AX column was last used, etc.

While the detected amounts of impurity generally remained a small percentage of the net composition, both *in vivo* and *in vitro* testing showed that the impurities stimulate bacterial growth. Oligonucleotides that were not purified by AX-HPLC but are otherwise treated the same did not display either of the peaks observed during SEC, and did not have a stimulatory effect. However, oligonucleotides that were AX-HPLC purified and desalted as described, but were not further purified by SEC showed either stimulatory effects or, where the amounts of the impurities were not high, neutral or a significantly reduced antibiotic effect.

Spectroscopic analysis (¹H-NMR, A₂₅₄ absorbance, GC-MS, and FAB and ESI positive ion mass spectrometry) pointed to a comparatively small, simple molecule, or mixture of similar components, that were eluted along with the oligo. These compound(s) coeluted with oligonucleotide during the reverse-phase concentration/desalting process. In particular, analysis by electrospray mass spectroscopy of small molecular weight material removed from an oligonucleotide preparation that had been purified on a Waters Protein Pak 40Q revealed complex mixture of amino compounds with the common feature of signals at m/z 58 and m/z 72. These two signals are derived from the N,N-diethyl-N-(2-hydroxypropyl) quarternary amino functional group used as the cationic absorption moiety on the Protein Pak Q SAX stationary phase. Electrospray analysis of similar material from a N,N,N-trimethyl quarternary amino polymer-based SAX phase (e.g., BioRad's

Macroprep Q) also yielded equivalent signals indicative of the cleavage of absorption sites from the stationary phase. These low molecular weight materials were removed by SEC, and were also removed by a combination of SCX and reverse phase chromatography.

The steep ramping required for concentration purposes did not permit conditions suitable for resolution of close-running materials. However, the SEC step outlined above was capable of sufficiently removing the impurities to allow the detection of a consistent pattern of antibiotic activity inherent in the presently described purified oligonucleotides. Accordingly, the SEC step provides a process that allowed for the consistent and predictable removal of the stimulatory impurities from the oligonucleotide preparations.

As discussed above, oligonucleotides that have been purified using different procedures (i.e., no chromatography steps) consistently showed antibiotic effects that were comparable to the oligonucleotides purified as outlined immediately above.

In some very non-polar oligonucleotides, such as total p-ethoxy and chimeras with p-ethoxy/2'-O-methyl RNAs components, the concentration of ethanol required to elute the oligonucleotides from the reverse-phase column was high enough to allow some removal of the low-absorbing high conductivity material prior to the elution of the oligonucleotides. However, the resolution was not sufficiently clean to allow straight-forward characterization. This separation was not observed with predominantly S-oligonucleotides.

The ability of the RP-column to provide any separation may also be affected by the base composition of the oligonucleotides as well as the type of linkages employed to construct the oligonucleotides. Typically, the use of ethanol provided more control over the elution process than acetonitrile, which has higher elution power than ethanol.

Additionally, the use of ethanol during this step has implications for cGMP validation.

Another feature of the RP step is that the great reduction of inorganic salt during the reverse-phase protocol
5 allows for the use of conductivity to monitor peak elution during the SEC separation. If the salt were not removed, the conductivity signal of the impurities would be masked by the signal from the salt, and conductivity would only be useful for monitoring gross system changes.

10 The alkyl amines and/or alkyl ammonium compounds present in the described impurity apparently act as a counter ion to the phosphodiester and/or associated to the polar portions of the triester groups of the antibacterial oligonucleotides. The impurity material can not be isolated from blank runs of
15 solutions, reagents, and stationary phases used during the described synthesis and purification procedures. Presently, the impurity has only been observed in oligonucleotides that have been AX purified.

Further characterization (by spectroscopic analysis) of
20 the stimulatory impurities isolated during the SEC step revealed that they are apparently produced by cleavage of absorption sites on the SAX stationary phase.

Although relatively crude oligonucleotide preparations were able to demonstrate significant inhibition in this assay
25 (after substantial removal of the contaminants that normally hinder the antibacterial effects of oligonucleotides), FDA requirements for parenteral therapeutics necessitate higher levels of purification for animal and human use.

30 5.6. Antigene Antibacterial Oligonucleotide Activity

Antibacterial oligonucleotides 96ss (SEQ ID NO. 79) and 73ss (SEQ ID NO. 124) (the ss denotes that oligonucleotide 73 is targeted to the sense strand) are homologous to the sense strand of the targeted sequences. Oligonucleotides 96ss and
35 73ss are thought to exert antibacterial activity by acting as antigene sequences that block gene expression by forming a triple-stranded complex (i.e., triplex formation), or,

possibly, by directly interacting with bacterial proteins. A time course of the antibacterial activity of oligonucleotides 73ss and 96ss is shown in Table 7.

5 5.7. The Use of Antibacterial Oligonucleotides Against Antibiotic Resistant Bacteria

The presently described antibacterial oligonucleotides are also capable of inhibiting the growth of a variety of bacteria that are known to be resistant to various traditional antibiotics. Tables 8(A-C and F) test the inhibitory activity of oligonucleotide 73 (NBT 73 - SEQ ID NO. 124) against clinical isolates of *Escherichia coli* that are known to be resistant to: streptomycin (8A); sulfonamide (8B); penicillin (8C); as well as multiple drug resistant *Escherichia coli* (8F). Oligonucleotide 114 (SEQ ID NO. 112) also inhibited the growth of *Salmonella typhimurium* ATCC accession No. 23564 (8D), *Klebsiella pneumoniae* ATCC accession No. 4352 (8E), and *Staphylococcus aureus* ATCC accession No. 29213 (8G).

Tables 9(A-G) test the inhibitory activity of oligonucleotide 114 (NBT 114 - SEQ ID NO. 112) against clinical isolates of *Escherichia coli* that are known to be resistant to: streptomycin (9A); sulfonamide (9B); penicillin (9C); as well as multiple drug resistant *Escherichia coli* (9F). Oligonucleotide 114 (SEQ ID NO. 112) also inhibited the growth of *Salmonella typhimurium* ATCC accession No. 23564 (9D), *Klebsiella pneumoniae* ATCC accession No. 4352 (9E), and *Staphylococcus aureus* ATCC accession No. 29213 (9G).

Additional studies revealed that antibacterial oligonucleotides 114 (SEQ ID NO. 112), 5 (SEQ ID NO. 152), 39 (SEQ ID NO. 30), 43 (SEQ ID NO. 34), 3 (SEQ ID NO. 51), 78 (SEQ ID NO. 134), 12 (SEQ ID NO. 153), 14 (SEQ ID NO. 154), 23 (SEQ ID NO. 158), 24 (SEQ ID NO. 159), 22 (SEQ ID NO. 157), 17 (SEQ ID NO. 83), 20 (SEQ ID NO. 84), 15 (SEQ ID NO. 81), 16 (SEQ ID NO. 82), 19 (SEQ ID NO. 66), 28 (SEQ ID NO. 96), 63 (SEQ ID NO. 130), 10 (SEQ ID NO. 17), and 18 (SEQ ID NO. 73) significantly inhibited the growth of multiple drug

resistant *Escherichia coli* ATCC accession No. 35218 for over 400 minutes when present at a concentration of about 0.5-2.0 mg/ml as shown in Figures 6(a-t).

Additionally, antibacterial oligonucleotides 16 (SEQ ID NO. 82), 18 (SEQ ID NO. 73), 1 (SEQ ID NO. 119), 5 (SEQ ID NO. 152), 17 (SEQ ID NO. 83), 21 (SEQ ID NO. 156), 132 (SEQ ID NO. 15), 11 (SEQ ID NO. 18), 89 (SEQ ID NO. 61), and 2 (SEQ ID NO. 50) all inhibited the growth of penicillin resistant clinical isolates of *Staphylococcus aureus* ATCC accession No. 13301 for over 400 minutes when present in the culture medium at a concentration of about 0.5-2.0 mg/ml (data are respectively provided in Figures 7(a-j)).

Oligonucleotide 14 (NBT 14 - SEQ ID NO. 154) was used to test whether the antibacterial oligonucleotides could also be used to enhance a target bacteria's sensitivity to antibiotics to which the bacteria had previously proven resistant. Table 10 shows the results of a growth inhibition time course experiment where oligonucleotide 14 was tested for the ability to inhibit the growth of *Escherichia coli* Y1088 (known to be resistant to ampicillin) in the presence and absence of the indicated concentration of ampicillin (50 µg/ml, and 250 µg/ml). Table 10 indicates that oligonucleotide 14 is capable of significantly restoring ampicillin sensitivity of *Escherichia coli* Y1088.

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5.8. Animal Studies

Preliminary assessments of the *in vivo* efficacy of the presently described antibacterial oligonucleotides (using a Lister & Saunders test) indicate that a higher percentage of animals treated with oligonucleotide survive exposure to near-lethal amounts of *Escherichia coli* ATCC accession No. 25922 (prepared and injected as described in Lister & Saunders, 1995). In particular, Figure 8 shows that mice treated with oligonucleotide 114 (SEQ ID NO. 112) *in vivo* proved more resistant to challenge by a bacterial pathogen than control animals. The assay was conducted essentially as described in section 4.6, *supra*, and involved a total of 5 mg

of oligonucleotide injected (I.P.) over a 2 day period (1 mg of oligonucleotide suspended in 0.5 ml of sterile saline was injected at 1, 5, 10, 24, and 34 hours post infection). Additionally, Figure 9 shows that mice treated with the 5 antibacterial oligonucleotide SOT 114.21 (phosphorothioate GGAACGCGC linked to 2'-methoxy riboCATTTGGTATATC with an inverted 3' terminal deoxythymidine) had substantially enhanced survival after challenge with lethal quantities (approximately 10^8 cfu in mucin and iron dextran injected i.p. 10 into CD1 mice) of *Staph. Aureus*. In Figure 9, treatment with *Staph.* was T=0 and 5 hours after infection. Oligonucleotide treatment was only administered on day 1.

Subsequent *in vivo* studies have shown that SOT 114.21 can increase the survival of *Staph. Aureus* challenged test 15 animals by about 81 percent, and increase the survival of *E. coli* infected test animals by about 95 percent (relative to animals treated with a placebo).

Similarly, when a representative antibacterial oligonucleotide was tested using the model of Hof et al., 20 additional evidence of *in vivo* efficacy was obtained. In particular, Table 11 shows that mice treated with oligonucleotide 132 (SEQ ID NO. 15) *in vivo* had markedly reduced amounts of bacteremia 24 hours after initial exposure to *Escherichia coli* ATCC accession No. 25922 (prepared and 25 injected as described in Hof et al., 1986). This assay was conducted essentially as described in section 4.6, and involved the injection of a total of 2 mg of oligonucleotide (1 mg injected at 6 and 10 hours post infection).

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5.9. Standard MIC Assays

To eliminate the possibility that the observed antibacterial activity might be a function of the slightly modified version of the MIC used to generate the above data, antibacterial assays were conducted using the standard MIC assay. Given that 44 percent of all nosocomial infections are caused by *Staph. aureus*, *Streptococcus*, or *Pseudomonas*, these bacteria were used as targets for standard MIC assays.

10 In brief, the standard MIC assay was conducted by using 10x13 mm tubes to which 40 μ l of Mueller Hinton Broth (purchased from BBL, obtained through VWR, 3745 Bayshore Blvd., Brisbane, CA 94005) was added. The oligonucleotides (including an oligo dT control) were supplied as lyophilized

15 pellets and dissolved in 200 μ l of sterile tissue culture water (Sigma), and 200 μ l aliquots of water or dissolved oligonucleotide were then added to the "control" or "oligo test" tubes.

Bacterial suspensions were prepared by suspending the

20 organisms in 1.0 ml of sterile-filtered saline (Sigma) at a concentration corresponding to an O.D.₆₂₅ of 0.1-0.102. Ten μ l of this suspension was then added to 990 μ l of saline and 500 μ l of this mixture was added to both the "control" and "oligo test" tubes (a concentration of approximately 1×10^5

25 bacteria per ml). Sterile saline was added (260 μ l) to each of test tube to reach a total volume of 1 ml, the tubes were vortexed, O.D.₆₂₅'s were measured (time zero), and tubes were incubated at 35° C for 16-24 hours (without shaking). Tubes were vortexed in the morning, and the amount of bacterial

30 growth (if any) was measured by measuring O.D.₆₂₅ readings.

Results from studies using the standard MIC assay are described in Figures 10 through 13.

The antibacterial oligonucleotides used in the following studies were constructed as follows (5' to 3'):

35 SOT T12, 12 thymidines (first six bases phosphorothioate deoxynucleotides, followed by six 2'-methoxy ribonucleotides and an inverted 3' terminal deoxythymidine linked by a 3'-3'

phosphodiester linkage); SOT-C12, 12 cytidines (first six bases phosphorothioate deoxynucleotides, followed by six 2'-methoxy ribonucleotides and an inverted 3' terminal deoxythymidine); SOT 89.6 (phosphorothioate deoxyCAT linked 5 to 2'-methoxy riboGTC with an inverted 3' terminal deoxythymidine); SOT 89.9 (phosphorothioate deoxyCATGT linked to 2'-methoxy riboCATT with an inverted 3' terminal deoxythymidine); SOT 89.12 (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTCTC with an inverted 3' terminal 10 deoxythymidine); SOC 89.12 (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTCTC with a 3' terminal cholesteryl group); SOB 89.12 (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTCTC with a 3' terminal biotin group); MMT 89.12 (89.12 with all methoxyribonucleotides 15 linked to an inverted 3' terminal deoxythymidine); MPT 89.12 (the 89.12 sequence, CATGTCATTCTC, with all p-ethoxy, 2'-methoxy RNA linked to an inverted 3' terminal deoxythymidine); SOPT 89.12 (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTC followed by p-ethoxy, 2'- 20 methoxy riboTC linked to an inverted 3' terminal deoxythymidine); POT 89.12 (89.12 with all p-ethoxy DNA linked to an inverted 3' terminal deoxythymidine); DSM 89.18 (phosphorothioate deoxyCATGTCAT linked to phosphorothio (i.e., sulphur), 2'-methoxyriboTCTCCTTAAG linked to a 3'- 25 terminal deoxythymidine); SSM 89.18 (sulphur, 2'-methoxy riboCATGTCATTCTCCTTAAG linked to a 3'-terminal deoxythymidine); NBT 89.15 (phosphorothioate deoxy CATGTCATTCTCCTT linked to an inverted 3' terminal deoxythymidine); NBPT 89.12 (phosphorothioate deoxyCATGTC, 30 linked to 2'-methoxy riboATTC, followed by p-ethoxy, 2'-methoxy riboTC linked to an inverted 3' terminal deoxythymidine); MMPT 89.12 (2'-methoxy riboCATGTCATTC linked to p-ethoxy, 2'-methoxy riboTC, linked to an inverted 3' terminal deoxythymidine); SST 89.12 (phosphorothioate 35 deoxyCATGT linked to sulphur, 2'-methoxy riboCATTCTC linked to an inverted 3' terminal deoxythymidine); SOT 1.15 (phosphorothioate deoxyTGTGTA, linked to 2'-

methoxyriboGCCCATAGT, linked to an inverted 3' terminal deoxythymidine); SOT 5 (phosphorothioate deoxyTTGAC linked to 2'-methoxy riboATATCGGTCACTC linked to an inverted 3' terminal deoxythymidine); SOT 143.15 (phosphorothioate 5 deoxyCTCATG linked to 2'-methoxyriboATTAACACC linked to an inverted 3' terminal deoxythymidine); SOM-89 (a sulphur, 2'-methoxyriboC, linked to phosphorothioate deoxyGCCA, linked to 2'-methoxyriboTGTCATTCTCCT, linked to sulphur, 2'-methoxyriboTAA, linked to a 3' terminal deoxyguanine); SOM 10 72.1 (a 5' sulphur, 2'-methoxyriboA, linked to phosphorothioate deoxyCTGA, linked to 2'-methoxyriboTGACTTCATGAT, linked to sulphur, 2'-methoxyriboGCG, linked to a 3' terminal deoxycytosine); SOT 89.21 (phosphorothioate deoxyCGCCATGT linked to 2'-methoxyriboCATTCTCCTTAAG linked to an inverted 3' terminal deoxythymidine), SOM 114 (phosphorothioate deoxyGGAACGCG, linked to 2'-methoxyriboCCATTGGTA, linked to sulphur, 2'-methoxyriboTAT, linked to a 3' terminal deoxycytidine), MMT 89.12 (2'-methoxyriboCATGTCATTCTC linked to an inverted 3' 20 terminal deoxythymidine); 132 (SEQ ID NO. 15), SOM 1.1 (sulphur, 2'-methoxyriboA, linked to phosphorothioate deoxyGCAA, linked to 2'-methoxyriboCTGTGTAGCCCA, linked to sulphur, 2'-methoxyriboTAG, linked to a 3' terminal deoxythymidine, SOM 72.1, or SOM 5.1 (sulphur, 2'-methoxyT, 25 linked to phosphorothioate deoxyACTT, linked to 2'-methoxyriboGACATATCGGTC, linked to sulphur, 2'-methoxyriboACT, linked to a 3' terminal deoxycytidine), and mixtures of SOT(5.15, 78.15, 89.15, and 114.15) or SOT(89.18, 114.15 (phosphorothioate deoxyCGCCAT linked to 2'-methoxyriboTGGTATATC linked to an inverted 3' terminal deoxythymidine), and 78.15 (phosphorothioate deoxyCATTGT linked to 2'-methoxyriboTTGTACTCC linked to an inverted 3' terminal deoxythymidine).

Figures 10a and 10b show the results of standard 35 overnight MIC assays using the indicated oligonucleotides to test for antibacterial activity against *Staph. aureus*. Virtually all of the oligonucleotides tested (SOT-T12, SOT-

C12, SOT 89.(6, 9, and 12), SOC 89.12, SST 89.12, SOT 1.15, SOT 5.15 (phosphorothioate deoxyACATAT linked to 2'-methoxyriboCGGTCACTC linked to an inverted 3' terminal deoxythymidine), and SOT 143.15) significantly inhibited the growth of *Staph. aureus* (with the exception of the oligo dT string) relative to the control samples.

Figures 11a and 11b show the antibacterial activity of oligonucleotides DSM 89.18, SOT 78.15 (phosphorothioate deoxyCATTGT linked to 2'-methoxyriboTTGTACTCC linked to an inverted 3' terminal deoxythymidine), SOM 114.15, SOT 89.18 (phosphorothioate deoxyCATGTCAT linked to a 2'-methoxyriboTCTCCTTAAG, linked to an inverted 3' deoxythymidine), SOT 89.21, NBT 89.15, NBT 89.12-1 (phosphorothioate deoxyCATGTCATTCTC linked to a 3' terminal inverted phosphorothioate deoxythymidine), NMPT 89.12-2 (phosphorothioate deoxyCATGTCATTC linked to 2'-methoxy TC, linked to an inverted 3' terminal deoxythymidine); MPT 89.12-4 (CATGTCATTCTC, with all p-ethoxy, 2'-methoxy RNA linked to an inverted 3' terminal deoxythymidine); MMPT 89.12-5 (2'-methoxy riboCATGTCATTC linked to p-ethoxy, 2'-methoxy riboTC, linked to an inverted 3' terminal deoxythymidine); SOT 89.12-6 (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTCTC with an inverted 3' terminal deoxythymidine); SOPT 89.12-7 (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTC followed by p-ethoxy, 2'-methoxy riboTC linked to an inverted 3' terminal deoxythymidine) when measured in standard overnight MIC assays against *Serratia liquefaciens*. As is readily apparent, all of the test oligonucleotides displayed significant antibacterial activity relative to controls.

Interestingly, the oligonucleotides used in Figures 10-11 retained antibacterial activity when used in standard overnight MIC assays over the three day time course. These data indicate that the tested antibacterial oligonucleotides are bactericidal for the test microorganisms.

Figure 12 shows the level of growth inhibition obtained when the oligonucleotides SOC 89.12, SOB 89.12, MMT 89.12,

MPT 89.12, SOPT 89.12, POT 89.12, DSM 89.18, SSM 89.18, NBT 89.15, NBPT 89.12, MMPT 89.12, SOT 89.12, and SOM-89F were tested in a standard MIC assay against *Staph. aureus*. All of the tested oligonucleotides proved effective at inhibiting the growth of *Staph. aureus*.

Figure 13 shows that several different length variants (6mers, 12mers, 15mers, 18mers) (phosphorothioate deoxyCATGTC linked to 2'-methoxy riboATTCTCCTT linked to an inverted 3' terminal deoxythymidine), and 18mers) were able to inhibit the growth of *Staph. aureus* when they were tested in a standard MIC assay against *Staph. aureus*.

Figures 14(a and b) compare the antibacterial activities of the conventional antibiotic ampicillin and SOT 114.21 against isolates of *Staph. aureus* strains 13301 and 29213.

Figure 15 shows that oligonucleotide MMT 114.15 (2'-methoxyriboCGCCATTGGTATATC' linked to an inverted 3' terminal deoxythymidine) proved capable of inhibiting the growth of *P. aeruginosa* strain 10145, an opportunistic Gram negative pathogen that has proved resistant to many conventional antibiotics, in a standard MIC assay.

Figure 16 shows that oligonucleotide SOT 114.21 proved capable of inhibiting the growth of the pathogen *Strep. pyogenes* strain 14289 in a standard MIC assay.

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EQUIVALENTS

The foregoing specification is considered to be sufficient to enable one skilled in the art to broadly practice the invention. Indeed, various modifications of the above-described methods for carrying out the invention which are obvious to those skilled in the field of microbiology, biochemistry, organic chemistry, medicine or related fields are intended to be within the scope of the following claims. All patents, patent applications, and publications cited are incorporated herein by reference.

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TABLE 1

| Table 1 | | | | | |
|---|---------------|--------------------|--------------------|------------------|-------------------------------------|
| Antimicrobial Susceptibility According to NCCLS Standards | | | | | |
| Gene/ Operon Target | NBT Number | Drug R Gram Neg | Drug R Gram Pos | SEQ ID NO. | Sequence |
| Category of Target: Energy Metabolism | | | | | |
| hemA | NBT 28 | 97% INH | 100% INH | 1 | AAG GGT CAT GTC TGC GGG AAA TAA TAC |
| aroC | NBT 32 | 97% INH | 57% INH | 2 | CCG TTA TTG TTG TGT TTG CGT GTT TAC |
| aroA | NBT 36 | | | 3 | CAG GGA TTC CAT GAA ACT CAA CTC TCA |
| chaC | NBT 47 | | | 4 | ACA CTT CCG CCA CTG CAT ACT TCC CTG |
| chaB | NBT 48 | | | 5 | TCG TTT TAT ACG GCA TCG TTG ACT CCT |
| chaA | NBT 49 | | | 6 | GAC ATT ATG GTT ATC CCT TTG CAG ATG |
| ATP operon | NBT 57 | 56% INH | | 7 | TTC ACT CCT GCT CCC TTC GAG GTA TGC |
| hemD | NBT 61 | | | 8 | GCG GGT GAC AAG GAT ACT CAT GCC GGG |
| hemX | NBT 62 | | | 9 | CAT TAT GGC TTC CTG TTA TGA GAG TTA |
| moa operon | NBT 67 | | | 10 | GTT GTG AAG CCA TGT ACA CCT TTC CAG |
| crp | NBT 84 | 78% INH | 26% INH | 11 | GTT TGC CAA GCA CCA TGC GCG GTT TAC |
| ATPase | NBT 88 | 72% INH | | 12 | CGT CAT ATT TTC TGA AGC CAT GAT GCC |
| cya | NBT 104 | | | 13 | GGT ACA AGA CGT ATC GCC TGA TTT GCT |
| pckA | NBT 126 | | | 14 | CAT TTC TCA GCT CCT TAG CCA ATA TGT |
| fadD | NBT 132 | 89% INH | 100% INH | 15 | AGC CAA ACC TTC TTC AAT TCT TCA CCT |
| Category of Target: DNA Replication | | | | | |
| gyrA | NBT 9 | 100% INH | 33% INH | 16 | AAG GTC GCT CAT CTA ACC GCT ATC CCT |
| | NBT 10 | | | 17 | AGG TAA TTC AGC CAT CAA GAG TTC CTC |
| gyrB | NBT 11 | 96% INH | 100% INH | 18 | AAT GCA GTC ACC ATC GCT TTC TGT TAC |
| lig | NBT 26 | | | 19 | GCA TCA GCC TGT CGT ATT CAG CGT CGG |
| dnaG | NBT 30 | | | 20 | CGG CTC GTT TTC ACG TAC TTT AAT TAC |
| ssb | NBT 37 | | | 21 | TCT GCT GGC CAT AAT TGA GTC TCC TGA |
| groESL | NBT 66 | 63% INH | | 22 | ATA ACT CTC CTT TGA GAA AGT CCG TAT |
| dna A operon | NBT 79 | 65% INH | | 23 | AAG CGA AAG TGA CAC GGC GGA CTC CAC |
| dnaT operon | NBT 81 | | | 24 | GGT CAT CAA GAT CAT TCG GGA ACC ATG |
| parC | NBT 95 | | | 25 | TCG CTC ATT AAT TCT GAT TCC TCA ACT |
| hold | NBT 109 | | | 26 | TAA CTG CCA GTC TCG TCG GGA TGT CAT |
| dnaQ | NBT 124 | | | 27 | CGT GTA ATT GCA GTG CTC ATA GCG GTC |
| dnaE | NBT 130 | | | 28 | TGT ACG AAA CGT GGT TCA GAC ATC TTC |
| dnaJ | NBT 133 | | | 29 | CTC GTA ATA ATC TTG CTT AGC CAT CTT |
| Category of Target: Cell Division Control | | | | | |
| minB | NBT 39 | 100% INH | 34% INH | 30 | TGA CAT CCT GGC CTT ACT CAA TTA GCT |
| minD | NBT 40 | | | 31 | CAA CAA TAA TGC GTG CCA TAG AAA TTC |
| minE | NBT 41 | | | 32 | GAG TAA TGC CAT AAC TTA TCC TCC GAA |
| ftsW | NBT 42 | | | 33 | AAC GCA TCA ACC TAA CTC CTT CGC CAG |
| ftsN | NBT 43 | 100% INH | | 34 | TAT TTA TTC GTT CGT CAG CCC GCC ATG |

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| Table 1 | | | | | | |
|---|---|----------|----------|----------------------------|---|--|
| Antimicrobial Susceptibility According to NCCLS Standards | | | | | | |
| ftsH | NBT 44 | | | 35 | GAA CGC TTC TTA CCT GTC ATT TAA CTT | |
| ftsJ | NBT 45 | | | 36 | GTA TTA GGT TTT TCG CCA TGT CAC TCA | |
| ftsQ | NBT 52 | | | 37 | TTC AGA GCA GCC TGC GAC ATA TTA GAC | |
| ftsA | NBT 53 | | | 38 | CGT CGC CTT GAT CAT TGT TGT TCT GCC | |
| ftsZ | NBT 54 | | | 39 | ATT GGT TCA AAC ATA GTT TCT CTC CGA | |
| parB | NBT 55 | | | 40 | TGG ATG TTT CAT GGC CTT CTC CTT | |
| fts YEX operon | NBT 65 | 60% INH | 21% INH | 41 | CTA CAC TCC TCG CTG TTG CTT CAT GGC | |
| pbpB | NBT 80 | 90% INH | 42% INH | 42 | TGC TTT CAT GCG TCG CGT TTA TCC TTA | |
| rodA | NBT 83 | | | 43 | TTA TCC GTC ATG ATT AAT GGT CCT CCG | |
| tig | NBT 119 | | | 44 | GCA TCT TGT TAC CTC AAA AAA TCA CAG | |
| Category of Target: Regulatory Proteins | | | | | | |
| lon | NBT 27 | 97% INH | 100% INH | 45 | AGG ATT CAT AGA GCT CTC TAG TTT | |
| rel B | NBT 56 | | | 46 | TTA ACA TCT TTT GCT GCT GCT TCA TAG | |
| crp | NBT 84 | 78% INH | 26% INH | 47 | GTT TGC CAA GCA CCA TGC GCG GTT TAC | |
| lexA | NBT 131 | | | 48 | GCC TGG CCG TTA ACG CTT TCA TTC CGC | |
| Category of Target: Cell Wall Biosynthesis | | | | | | |
| asd | NBT 1 NBT 2 NBT 3 NBT 7 NBT 8 | 97% INH | 100% INH | 49 50 51 52 53 | AAC GAT AGC AAC TGT GTA GCC CAT AGT ACG AGT TCC ACC GGC GCC TGT AGC ACC GGA GCC GAC CAT ACC GCG CCA GCC GAT CAA CAA CTG CGA TGG TGG TCA TTG TAA ACC GCG CCA GCC GAC GAA ACC TAC TTT | |
| ddlA | NBT 33 NBT 34 NBT 35 | 70% INH | 26% INH | 54 55 56 | CGT CTA ACA CAA AGT GCA TAC ATT ACC CAC TTC ATG TTG CGC TGA TTT ACC ACC CCA TCT TAA AAA CCT ATC CCG TCT AAC | |
| murG | NBT 50 | | | 57 | CTT GAC CAC TCA TCG TGA ACC TCG TAC | |
| murC | NBT 51 | | | 58 | GTT GTG TAT TCA TTC TTT ACG CCA TTA | |
| lysA | NBT 6 | | | 59 | CAG TGA ATG TGG CAT AAC AAA CTC CAG | |
| murD | NBT 139 | | | 60 | CGT ACC TTC AGC GTT GCC AGA CCA ATC | |
| Category of Target: Sugar Metabolism | | | | | | |
| zwf | NBT 89 | 69% INH | 100% INH | 61 | CGT TAC CGC CAT GTC ATT CTC CTT AAG | |
| sdhB | NBT 112 | | | 62 | CTG TCT CCG CAT TAG TAA GTA CGA ATC | |
| Category of Target: Virulence, Pili, Flagella | | | | | | |
| pap operon | NBT 72 | 31% INH | | 63 | TGA CCG ACT GAT GAC TTC ATG ATG CGC | |
| rim J | NBT 103 | 76% INH | | 64 | CAT TCT ATA CCT ACT CCT TCC CGT AAC | |
| Category of Target: Fatty Acid Metabolism | | | | | | |
| fadD | NBT 132 | 89% INH | 100% INH | 65 | AGC CAA ACC TTC TTC AAT TCT TCA CCT | |
| Category of Target: mRNA Synthesis/Stability | | | | | | |
| rpoN operon | NBT 19 | 100% INH | 23% INH | 66 | TAG GAT GTT CTA ACC TTT TCA ATC AGC | |
| alpha operon | NBT 29 | 98% INH | | 67 | TAC GGG CCA CTA TGC ACT CCT ACT ATT | |
| MMS operon | NBT 30 | | | 68 | CGG CTC GTT TTC ACG TAC TTT AAT TAC | |
| rho | NBT 125 | | | 69 | GAT TCA TAG TGG TGT GAG TTC TTA AAC | |
| rnpB | NBT 121 | | | 70 | GAA GAG GAC GAC GAC GAA GCG GCG ACT | |

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| Table 1 | | | | | | | | | |
|---|---------|----------|----------|-------------------------|-------------------------------------|--|--|--|--|
| Antimicrobial Susceptibility According to NCCLS Standards | | | | | | | | | |
| ams | NBT 134 | | | 71 | TCA TCG TAA CTT ACT CAT TAT TCT TAC | | | | |
| Category of Target: tRNA Synthesis | | | | | | | | | |
| trm D | NBT 16 | 100% INH | 100% INH | 72 | GCT AAA CGA ATA GTT ACC ATA ACA TCC | | | | |
| met Y | NBT 18 | 100% INH | 100% INH | 73 | TAA TCA TCT CTG CTA ATT TTG CTC TAA | | | | |
| | 174 | | | TCA TCT CTG CTA | | | | | |
| | 175 | | | TCA TCT CTG CTA ATT | | | | | |
| | 176 | | | TCA TCT CTG CTA ATT TTG | | | | | |
| val U operon | NBT 91 | | | 74 | GTG CTC TCC CAG CTG AGC TAA TCA CCC | | | | |
| | NBT 92 | | | 75 | CTC TCC CAG CTG AGC TAA TCA CCC | | | | |
| tRNA operon | NBT 93 | | | 76 | CGC TCT ATC CAG CTG AGC TAC GGG CGC | | | | |
| | NBT 94 | | | 77 | TCT ATC CAG CTG AGC TAC GGG CGC | | | | |
| infA operon | NBT 100 | | | 78 | TCA CAA TAA ACT CCT TAC CAT CCC ATT | | | | |
| Category of Target: rRNA Synthesis | | | | | | | | | |
| rrnB operon | NBT 96 | 80% INH | | 79 | GCC GCC AGC GTT CAA TCT GAG TGA | | | | |
| Category of Target: Ribosomal Protein Synthesis | | | | | | | | | |
| str operon | NBT 12 | 97% INH | | 80 | AAC TGT TGC CAT TAA ATA GCT CCT GGA | | | | |
| slo operon | NBT 15 | 100% INH | 40% INH | 81 | GCG GAT ACG GAT TCT TTG GTT CTG CAT | | | | |
| trmD operon | NBT 16 | 100% INH | 100% INH | 82 | GCT AAA CGA ATA GTT ACC ATA ACA TCC | | | | |
| spc operon | NBT 17 | 100% INH | 98% INH | 83 | GTT CAG CAT AGT CTG TTC TTG GAT CAT | | | | |
| S15 operon | NBT 20 | 99% INH | 100% INH | 84 | AGC TGT TGC TTC AGT ACT TAG AGA CAT | | | | |
| S12 operon | NBT 21 | 82% INH | 100% INH | 85 | TTG TAG GCA TCT ACA TTC TCC TGT GTT | | | | |
| alpha operon | NBT 29 | 98% INH | | 86 | TAC GGG CCA CTA TGC ACT CCT ACT ATT | | | | |
| MMS operon | NBT 30 | | | 87 | CGG CTC GTT TTC ACG TAC TTT AAT TAC | | | | |
| tsf | NBT 38 | 67% INH | 46% INH | 88 | AAA CAG TTG CCA TGA TTA TTT CCT CTA | | | | |
| rim J | NBT 103 | 78% INH | | 89 | CAT TCT ATA CCT ACT CCT TCC CGT AAC | | | | |
| rim I | NBT 107 | | | 90 | TTT CGA GGG AAG AAA TCG TGT TCA TAT | | | | |
| | NBT 108 | | | 91 | GTG GTA AGC CGC CGG TAA ATC AGT CGT | | | | |
| rnpA | NBT 122 | | | 92 | TTA CTT AGA AAC GGT CAG ACG AGC GCG | | | | |
| rpmH | NBT 123 | | | 93 | GCG TTT CAT GGC GAT TTC TAC CTA AAC | | | | |
| Category of Target: Protein Synthesis | | | | | | | | | |
| str operon | NBT 12 | 97% INH | | 94 | AAC TGT TGC CAT TAA ATA GCT CCT GGA | | | | |
| nusA operon | NBT 18 | 100% INH | 100% INH | 95 | TAA TCA TCT CTG CTA ATT TTG CTC TAA | | | | |
| hemA | NBT 28 | 97% INH | 100% INH | 96 | AAG GGT CAT GTC TGC GGG AAA TAA TAC | | | | |
| infC | NBT 31 | | | 97 | TCC GCC TTT AAT ACC TTA TTC CTC CAA | | | | |
| tsf | NBT 38 | 100% INH | 46% INH | 98 | AAA CAG TTG CCA TGA TTA TTT CCT CTA | | | | |
| prf | NBT 90 | | | 99 | GGC TTC ATA GGC GTA AAT TCA CCC TGT | | | | |
| infA operon | NBT 110 | | | 100 | GCA ACA AAC AGG TTC GGC ACA TTA CTC | | | | |

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| Table 1 | | | | | | | | | |
|---|---------|----------|----------|-----|-------------------------------------|--|--|--|--|
| Antimicrobial Susceptibility According to NCCLS Standards | | | | | | | | | |
| aat | NBT 135 | | | 101 | TAT TGA ATG GCG AGA AAG CAG AAC CAG | | | | |
| Category of Target: Phospholipid Synthesis | | | | | | | | | |
| adk | NBT 25 | 96% INH | 44% INH | 102 | CCG AAG CAG AAT AAT ACG CAT TAC GAA | | | | |
| psd | NBT 105 | 83% INH | 50% INH | 103 | AAA TGA ATT TAA CAA GGT AGC CTC CAG | | | | |
| pss | NBT 106 | | | 104 | CAG TGC ATT TCT TCT CTG TTC ATT GAA | | | | |
| Category of Target: Periplasmic/Secretory Proteins | | | | | | | | | |
| envA | NBT 46 | 59% INH | 25% INH | 105 | TTT GTT TGA TCA TCG TAT TAT CTC GCC | | | | |
| tolA | NBT 85 | | | 106 | CGG TTG CCT TTG ACA CTC TCG GTT TCC | | | | |
| tolB | NBT 86 | | | 107 | CCT GCT TCA TCA TAT CTC CCT ATA CTG | | | | |
| secA | NBT 118 | | | 108 | CTT TAG TTA ACA ATT TGA TTA GCA TAA | | | | |
| Category of Target: Transport Proteins | | | | | | | | | |
| biotin operon | NBT 58 | 84% INH | | 109 | GCG ACA ATG TCC AGC GTG GGC GGT GAG | | | | |
| | NBT 59 | | | 110 | ATC GGG CTT CTC CAA AAT ATG TTG TTT | | | | |
| | NBT 60 | | | 111 | GTT AAT TCG GTG TAG ACT TGT AAA CCT | | | | |
| fhuA | NBT 114 | 100% INH | 18% INH | 112 | GGA ACG CGC CAT TGG TAT ATC TCT GAT | | | | |
| fhuC | NBT 115 | | | 113 | TCC TGC ATA ACA GCC AAC TTG TGA TTA | | | | |
| jhuD | NBT 116 | | | 114 | TAA GAG GTA AGC CGC TCA TCA ATA AAC | | | | |
| fhuB | NBT 117 | | | 115 | CTG CGA GAA GTT CAT CCA GGT GAG CGC | | | | |
| Category of Target: Amino Acid Biosynthesis | | | | | | | | | |
| aroC | NBT 32 | 97% INH | | 116 | CCG TTA TTG TTG TGT TTG CGT GTT TAC | | | | |
| aroA | NBT 36 | | | 117 | CAG GGA TTC CAT GAA ACT CAA CTC TCA | | | | |
| nir operon | NBT 71 | 93% INH | 42% INH | 118 | ATA ATT GCG AGT CTG ACT TTG CTC ATT | | | | |
| asd | NBT 1 | 97% INH | 100% INH | 119 | AAC GAT AGC AAC TGT GTA GCC CAT AGT | | | | |
| | NBT 2 | | | 120 | ACG AGT TCC ACC GGC GCC TGT AGC ACC | | | | |
| | NBT 3 | | | 121 | GGA GCC GAC CAT ACC GCG CCA GCC GAT | | | | |
| | NBT 7 | | | 122 | CAA CAA CTG CGA TGG TGG TCA TTG TAA | | | | |
| | NBT 8 | | | 123 | ACC GCG CCA GCC GAC GAA ACC TAC TTT | | | | |
| Category of Target: Lipopolysaccharide Synthesis | | | | | | | | | |
| rfaY | NBT 73 | 100% INH | 36% INH | 124 | GTC TTT GAT CTT GCT CTT CTG AAT CAT | | | | |
| rfaZ | NBT 74 | | | 125 | TAT CTA ATA TTC TTC ATG ATA AAC CTG | | | | |
| rfaL | NBT 75 | | | 126 | TTC CTA AGC GCA TTT TTA TAC CAT ATT | | | | |
| rfaK | NBT 76 | | | 127 | TAA TGA TGA TAA CTT TTC CAA AAC TGC | | | | |
| lps operon | NBT 77 | 76% INH | | 128 | CCA TGA TAT CGC ATC TTT ATG ACC AGG | | | | |
| Category of Target: Purine/Pyrimidine Biosynthesis | | | | | | | | | |
| adk | NBT 25 | 96% INH | | 129 | CCG AAG CAG AAT AAT ACG CAT TAC GAA | | | | |
| deoC operon | NBT 63 | 100% INH | 51% INH | 130 | GCT TTC AGA TCA GTC ATT TCA TTC TCC | | | | |
| pyrE operon | NBT 64 | | | 131 | TTC ATC ATA ACG GGT CAC GAT CTC GTC | | | | |
| prs | NBT 111 | 87% INH | | 132 | CAT ATC AGG CAC CAG AAG AAC CTC AGG | | | | |
| gpt | NBT 128 | | | 133 | TTC GCT CAT GTG AAG TGT CCC AGC CTG | | | | |
| Category of Target: Outer Membrane Proteins | | | | | | | | | |
| ompB operon | NBT 78 | 100% INH | 33% INH | 134 | GTA GTT CTC TTG CAT TGT TTG TAC TCC | | | | |
| nlpA | NBT 87 | | | 135 | GGC TAG ATG ATG TGT TGT CAG TTT CAT | | | | |

| Table 1 | | | | | |
|---|---------|----------|----------|-----|-------------------------------------|
| Antimicrobial Susceptibility According to NCCLS Standards | | | | | |
| ompX | NBT 97 | | | 136 | CAT AAC CAC CTC AAA TGT GAT TCA AAT |
| ompF | NBT 98 | | | 137 | GCC AGA ATA TTG CGC TTC ATC ATT ATT |
| ompC | NBT 99 | | | 138 | TAA CTT TCA TGT TAT TAA CCC TCT GTT |
| ompH | NBT 100 | | | 139 | TCA CAA TAA ACT CCT TAC CAT CCC ATT |
| ompP | NBT 101 | | | 140 | CAG AAG CTT AGT TTG CAT AAC AAT GAC |
| ompA | NBT 102 | | | 141 | AAT CGC GAT AGC TGT CTT TTT CAT |
| tsx | NBT 120 | | | 142 | CAT ATG TAT GCC ACT GTT TGA AAA TCC |
| lpp | NBT 127 | 91% INH | 98% INH | 143 | GCC CAG TAC CAG TTT AGT AGC TTT CAT |
| envM | NBT 129 | | | 144 | ACC CAT AGC TTT AAT CCT TAT TGT TGA |
| envC | NBT 137 | | | 145 | GCA TGT TTC GTC ATT ACT ATT CCT CAA |
| envD | NBT 138 | | | 146 | GTT TGC CAT GTC AGA TTA CCT TAC TTC |
| envR | NBT 136 | | | 147 | TTT GCC ATG ATT AAT TAT TCA GGA AAT |
| Category of Target: Nitrate Reductase | | | | | |
| nar operon | NBT 68 | 70% INH | | 148 | ATT TAC TCA TCG GTT TTC TCC TGT GGG |
| nar XL operon | NBT 69 | | | 149 | AAG CAT GTA AAC CTC TTC CTT CAG GCT |
| nar ZYWZ operon | NBT 70 | | | 150 | GAT CCA AAA GTT TAC TCA TAG CAT GAC |
| nir operon | NBT 71 | 80% INH | 42% INH | 151 | ATA ATT GCG AGT CTG ACT TTG CTC ATT |
| Category of Target: Drug Resistance | | | | | |
| sulA | NBT 5 | 100% INH | 100% INH | 152 | TGG CTT TAC TTG ACA TAT CGG TCA CTC |
| str operon | NBT 12 | | | 153 | AAC TGT TGC CAT TAA ATA GCT CCT GGA |
| bla | NBT 14 | 99% INH | 98% INH | 154 | ACA CGG AAA TGT TGA ATA CTC ATA CTC |
| spc operon | NBT 17 | 100% INH | 98% INH | 155 | GTT CAG CAT AGT CTG TTC TTG GAT CAT |
| S12 operon | NBT 21 | 82% INH | 100% INH | 156 | TTG TAG GCA TCT ACA TTC TCC TGT GTT |
| tet resistance | NBT 22 | 100% INH | 90% INH | 157 | ATT GTT AGA TTT CAT ACA CGG TGC CTG |
| kan resistance | NBT 23 | 98% INH | 10% INH | 158 | CAT CTT GTT CAA TCA TGC GAA ACG ATC |
| ermC | NBT 24 | | | 159 | ACT GTG TTT TAT ATT TTT CTC GTT CAT |
| pbpB | NBT 80 | 90% INH | 42% INH | 160 | TGC TTT CAT GCG TCG CGT TTA TCC TTA |
| pbpA | NBT 82 | | | 161 | AAG AGT TCT GTA GTT TCA TCC GCT GCG |
| Category of Target: Vitamin Metabolism | | | | | |
| biotin operon | NBT 58 | 84% INH | | 162 | GCG ACA ATG TCC AGC GTG GGC GGT GAG |
| | NBT 59 | | | 163 | ATC GGG CTT CTC CAA AAT ATG TTG TTT |
| | NBT 60 | | | 164 | GTT AAT TCG GTG TAG ACT TGT AAA CCT |
| folic acid | NBT 5 | 100% INH | 100% INH | 165 | TGG CTT TAC TTG ACA TAT CGG TCA CTC |
| Category of Target: Miscellaneous | | | | | |
| IS | NBT 144 | 100% INH | | 166 | CCT CAT CAA ACA ATG |

| Table 1 | | | | | | | |
|---|---------|----------|--|-----|-------------------------------------|--|--|
| Antimicrobial Susceptibility According to NCCLS Standards | | | | | | | |
| (AT), | NBT 140 | 100% INH | | 167 | ATA TAT ATA TAT ATA TAT | | |
| (AC), | NBT 141 | 100% INH | | 168 | ACA CAC ACA CAC ACA CAC | | |
| (TC), | NBT 142 | 100% INH | | 169 | TCT CTC TCT CTC TCT CTC | | |
| (T), | NBT 13 | 100% INH | | 170 | TTT TTT TTT TTT TTT TTT | | |
| (C), | NBT 143 | 100% INH | | 171 | CCC CCC CCC CCC CCC CCC | | |
| sucA | NBT 113 | | | 172 | CAA AGC GCT GTT CTG CAT CGT GAT CCC | | |
| (RS) | NBT 4 | | | 173 | GAT ATC CGC ATG GTT CAA CAG ATG ACA | | |

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Table 2A. Energy Metabolism - Oligonucleotide #28

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|-------|--------|--|
| Time T=0 | Control | 28 | %Inhib | |
| 0 | 0 | 0.001 | 0 | |
| 60 | 0.002 | 0.001 | 50% | |
| 120 | 0.001 | 0.001 | 0% | |
| 180 | 0.003 | 0 | 100% | |
| 240 | 0.008 | 0 | 100% | |
| 285 | 0.015 | 0 | 100% | |
| 320 | 0.026 | 0 | 100% | |
| 350 | 0.04 | 0 | 100% | |
| 380 | 0.058 | 0.001 | 98% | |
| 410 | 0.076 | 0.002 | 97% | |
| 430 | 0.091 | 0.004 | 96% | |
| 450 | 0.105 | 0.004 | 96% | |

Table 2B. DNA Replication - Oligonucleotide #10

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|--------|--|
| Time T=0 | Control | 10 | %Inhib | |
| 0 | 0 | 0.003 | 0 | |
| 60 | 0.001 | 0.001 | 0% | |
| 120 | 0 | 0 | | |
| 170 | 0.003 | 0 | 100% | |
| 230 | 0.008 | 0 | 100% | |
| 275 | 0.017 | 0 | 100% | |
| 305 | 0.025 | 0 | 100% | |
| 340 | 0.046 | 0 | 100% | |
| 365 | 0.058 | 0 | 100% | |
| 385 | 0.075 | -0.002 | 103% | |
| 400 | 0.082 | -0.002 | 102% | |
| 415 | 0.094 | -0.002 | 102% | |
| 425 | 0.105 | 0.001 | 99% | |

Table 2C. Cell Division Control - Oligonucleotide #43

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|--------|--|
| Time T=0 | Control | 43 | %Inhib | |
| 0 | 0 | 0.005 | 0 | |
| 105 | 0.002 | -0.001 | 150% | |
| 175 | 0.003 | -0.004 | 233% | |
| 220 | 0.004 | -0.003 | 175% | |
| 270 | 0.007 | -0.003 | 143% | |
| 300 | 0.012 | -0.003 | 125% | |
| 330 | 0.022 | -0.003 | 114% | |
| 360 | 0.032 | -0.002 | 106% | |
| 395 | 0.052 | -0.001 | 102% | |
| 425 | 0.065 | 0 | 100% | |
| 445 | 0.081 | 0.001 | 99% | |
| 465 | 0.09 | 0.002 | 98% | |
| 490 | 0.108 | 0.008 | 93% | |

Table 2D. Regulatory Proteins - Oligonucleotide #27

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|--------|--|
| Time T=0 | Control | 27 | %Inhib | |
| 0 | 0 | 0.002 | 0 | |
| 60 | 0.002 | 0.001 | 50% | |
| 120 | 0.001 | 0.001 | 0% | |
| 180 | 0.003 | 0 | 100% | |
| 240 | 0.008 | 0 | 100% | |
| 285 | 0.015 | 0 | 100% | |
| 320 | 0.026 | 0 | 100% | |
| 350 | 0.04 | -0.001 | 103% | |
| 380 | 0.058 | 0.001 | 98% | |
| 410 | 0.076 | 0.002 | 97% | |
| 430 | 0.091 | 0.003 | 97% | |
| 450 | 0.105 | 0.003 | 97% | |

Table 2E. Cell Wall Biosynthesis - Oligonucleotide #2

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|---------|--|
| Time T=0 | Control | 2 | % Inhib | |
| 0 | 0 | 0.002 | 0 | |
| 105 | 0.002 | -0.001 | 150% | |
| 175 | 0.003 | -0.002 | 167% | |
| 220 | 0.004 | -0.001 | 125% | |
| 270 | 0.007 | -0.001 | 114% | |
| 300 | 0.012 | -0.001 | 108% | |
| 330 | 0.022 | -0.001 | 105% | |
| 360 | 0.032 | 0 | 100% | |
| 395 | 0.052 | 0 | 100% | |
| 425 | 0.065 | 0 | 100% | |
| 445 | 0.081 | 0.002 | 98% | |
| 465 | 0.09 | 0.003 | 97% | |
| 490 | 0.108 | 0.008 | 93% | |

Table 2F. Sugar Metabolism - Oligonucleotide #89

| Staphylococcus aureus 13301 | | | | |
|-----------------------------|---------|--------|---------|--|
| Time T=0 | Control | 89 | % Inhib | |
| 0 | 0 | 0.003 | 0 | |
| 90 | 0.002 | -0.002 | 200% | |
| 150 | 0.004 | -0.002 | 150% | |
| 210 | 0.008 | -0.002 | 125% | |
| 255 | 0.015 | -0.002 | 113% | |
| 285 | 0.026 | -0.001 | 104% | |
| 315 | 0.039 | -0.001 | 103% | |
| 345 | 0.052 | -0.001 | 102% | |
| 375 | 0.073 | -0.002 | 103% | |
| 395 | 0.08 | -0.001 | 101% | |
| 415 | 0.089 | -0.002 | 102% | |
| 435 | 0.103 | -0.002 | 102% | |

Table 2G. Virulence, Pili, Flagella - Oligonucleotide #103

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|---|--------|---------------|
| Time T=0 | Control | 0 | 103 | 0.004 % Inhib |
| 0 | 0 | 0 | 0 | |
| 60 | 0.001 | | -0.001 | 200% |
| 120 | 0.002 | | -0.002 | 200% |
| 180 | 0.006 | | -0.001 | 117% |
| 215 | 0.012 | | -0.001 | 108% |
| 250 | 0.02 | | 0 | 100% |
| 285 | 0.031 | | 0.001 | 97% |
| 325 | 0.072 | | 0.009 | 88% |
| 355 | 0.085 | | 0.015 | 82% |
| 375 | 0.096 | | 0.021 | 78% |
| 395 | 0.108 | | 0.026 | 76% |

Table 2H. Fatty Acid Metabolism - Oligonucleotide #132

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|---|--------|---------------|
| Time T=0 | Control | 0 | 132 | 0.003 % Inhib |
| 0 | 0 | 0 | 0 | |
| 60 | 0.001 | | -0.003 | 400% |
| 120 | 0.004 | | -0.002 | 150% |
| 165 | 0.007 | | -0.003 | 143% |
| 205 | 0.018 | | -0.002 | 111% |
| 235 | 0.028 | | -0.002 | 107% |
| 265 | 0.039 | | -0.001 | 103% |
| 295 | 0.063 | | 0.003 | 95% |
| 315 | 0.078 | | 0.004 | 95% |
| 335 | 0.093 | | 0.009 | 90% |
| 355 | 0.107 | | 0.013 | 88% |

Table 2I. mRNA Synthesis/Stability - Oligonucleotide #19

| Escherichia coli 35218 Multiple Drug Resistance | | | |
|--|-------------------|-------------|---------|
| Time T=0 | Control -0.001 | 19 0.005 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.001 | 200% |
| 150 | 0.002 | -0.001 | 150% |
| 195 | 0.005 | -0.001 | 120% |
| 245 | 0.013 | -0.002 | 115% |
| 275 | 0.019 | -0.001 | 105% |
| 320 | 0.04 | 0 | 100% |
| 350 | 0.054 | -0.002 | 104% |
| 365 | 0.066 | 0 | 100% |
| 385 | 0.079 | -0.002 | 103% |
| 415 | 0.095 | 0.003 | 97% |
| 430 | 0.105 | 0.001 | 99% |

Table 2J. tRNA Synthesis - Oligonucleotide #16

| Escherichia coli 35218 Multiple Drug Resistance | | | |
|--|--------------|-------------|---------|
| Time T=0 | Control 0 | 16 0.003 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.002 | 300% |
| 120 | 0 | -0.002 | |
| 170 | 0.003 | -0.002 | 167% |
| 230 | 0.008 | -0.002 | 125% |
| 275 | 0.017 | -0.004 | 124% |
| 305 | 0.025 | -0.004 | 116% |
| 340 | 0.046 | -0.004 | 109% |
| 365 | 0.058 | -0.004 | 107% |
| 385 | 0.075 | -0.004 | 105% |
| 400 | 0.082 | -0.004 | 105% |
| 415 | 0.094 | -0.004 | 104% |
| 425 | 0.105 | -0.002 | 102% |

Table 2K. rRNA Synthesis - Oligonucleotide #96

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|-------|---------|
| Time T=0 | Control | 96 | 0.005 | % Inhib |
| 0 | 0 | 0 | 0 | |
| 60 | 0.002 | -0.002 | 200% | |
| 120 | 0.004 | -0.005 | 225% | |
| 165 | 0.005 | -0.004 | 180% | |
| 210 | 0.011 | -0.003 | 127% | |
| 250 | 0.018 | -0.002 | 111% | |
| 275 | 0.025 | -0.001 | 104% | |
| 305 | 0.037 | 0.003 | 92% | |
| 340 | 0.056 | 0.013 | 77% | |
| 360 | 0.069 | 0.02 | 71% | |
| 380 | 0.08 | 0.028 | 65% | |
| 400 | 0.096 | 0.042 | 56% | |
| 420 | 0.108 | 0.053 | 51% | |

Table 2L. Ribosomal Protein Synthesis - Oligonucleotide #21

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|-------|---------|
| Time T=0 | Control | 21 | 0.002 | % Inhib |
| 0 | 0 | 0 | 0 | |
| 60 | 0.001 | -0.003 | 400% | |
| 120 | 0.004 | -0.002 | 150% | |
| 165 | 0.007 | -0.004 | 157% | |
| 205 | 0.018 | -0.001 | 106% | |
| 235 | 0.028 | -0.001 | 104% | |
| 265 | 0.039 | 0.001 | 97% | |
| 295 | 0.063 | 0.007 | 89% | |
| 315 | 0.078 | 0.01 | 87% | |
| 335 | 0.093 | 0.018 | 81% | |
| 355 | 0.107 | 0.025 | 77% | |

Table 2M. Protein Synthesis - Oligonucleotide #18

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|------------------|-------------|---------|--|
| Time T=0 | Control 0.001 | 18 0.017 | † Inhib | |
| 0 | 0 | 0 | | |
| 60 | 0.001 | -0.004 | 500% | |
| 120 | 0.002 | -0.004 | 300% | |
| 165 | 0.005 | -0.009 | 280% | |
| 210 | 0.015 | -0.01 | 167% | |
| 255 | 0.025 | -0.012 | 148% | |
| 285 | 0.041 | -0.01 | 124% | |
| 315 | 0.058 | -0.011 | 119% | |
| 335 | 0.073 | -0.009 | 112% | |
| 355 | 0.089 | -0.007 | 108% | |
| 375 | 0.101 | -0.006 | 106% | |

Table 2N. Phospholipid Synthesis - Oligonucleotide #105

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|--------------|--------------|---------|--|
| Time T=0 | Control 0 | 105 0.003 | † Inhib | |
| 0 | 0 | 0 | | |
| 60 | 0.001 | -0.003 | 400% | |
| 120 | 0.003 | -0.003 | 200% | |
| 180 | 0.008 | -0.002 | 125% | |
| 225 | 0.015 | -0.003 | 120% | |
| 260 | 0.026 | 0 | 100% | |
| 285 | 0.033 | 0.002 | 94% | |
| 315 | 0.047 | 0.008 | 83% | |
| 335 | 0.062 | 0.012 | 81% | |
| 355 | 0.075 | 0.022 | 71% | |
| 375 | 0.085 | 0.026 | 69% | |
| 395 | 0.101 | 0.04 | 60% | |

Table 20. Periplasmic/Secretory Proteins - Oligonucleotide #46

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|------------------|-------------|---------|--|
| Time T=0 | Control 0.002 | 46 0.004 | ‡ Inhib | |
| 0 | 0 | 0 | | |
| 60 | 0.001 | 0.001 | 0‡ | |
| 120 | 0.001 | 0.002 | -100‡ | |
| 180 | 0.001 | 0 | 100‡ | |
| 240 | 0.005 | 0.001 | 80‡ | |
| 285 | 0.012 | 0.001 | 92‡ | |
| 350 | 0.027 | 0.003 | 89‡ | |
| 390 | 0.043 | 0.012 | 72‡ | |
| 420 | 0.063 | 0.018 | 71‡ | |
| 450 | 0.082 | 0.028 | 66‡ | |
| 470 | 0.096 | 0.039 | 59‡ | |
| 500 | 0.106 | 0.046 | 57‡ | |

Table 2P. Transport Proteins - Oligonucleotide #114

| Salmonella typhimurium 23564 | | | | |
|------------------------------|------------------|--------------|---------|--|
| Time T=0 | Control 0.004 | 114 0.008 | ‡ Inhib | |
| 0 | 0 | 0 | | |
| 60 | -0.001 | 0 | | |
| 120 | 0 | -0.002 | | |
| 165 | 0 | -0.004 | | |
| 230 | 0.003 | -0.004 | 233‡ | |
| 260 | 0.005 | -0.004 | 180‡ | |
| 305 | 0.014 | -0.002 | 114‡ | |
| 335 | 0.021 | 0 | 100‡ | |
| 365 | 0.033 | 0.001 | 97‡ | |
| 395 | 0.052 | 0.007 | 87‡ | |
| 415 | 0.066 | 0.012 | 82‡ | |
| 435 | 0.08 | 0.018 | 78‡ | |
| 455 | 0.093 | 0.026 | 72‡ | |
| 476 | 0.108 | 0.035 | 68‡ | |

Table 2Q. Amino Acid Biosynthesis - Oligonucleotide #32

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|-------|---------|--|
| Time T=0 | Control | 32 | † Inhib | |
| | 0 | 0.002 | | |
| 0 | 0 | 0 | | |
| 60 | 0.002 | 0.001 | 50% | |
| 120 | 0.001 | 0 | 100% | |
| 180 | 0.003 | 0.001 | 67% | |
| 240 | 0.008 | 0.001 | 88% | |
| 285 | 0.015 | 0 | 100% | |
| 320 | 0.026 | 0 | 100% | |
| 350 | 0.04 | 0 | 100% | |
| 380 | 0.058 | 0.002 | 97% | |
| 410 | 0.076 | 0.002 | 97% | |
| 430 | 0.091 | 0.003 | 97% | |
| 450 | 0.105 | 0.003 | 97% | |

Table 2R. Lipopolysaccharide Synthesis - Oligonucleotide #73

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|---------|--|
| Time T=0 | Control | 73 | † Inhib | |
| | 0.006 | 0.005 | | |
| 0 | 0 | 0 | | |
| 60 | 0 | 0 | | |
| 120 | 0.001 | 0 | 100% | |
| 165 | 0.001 | 0 | 100% | |
| 210 | 0.005 | -0.001 | 120% | |
| 240 | 0.008 | 0 | 100% | |
| 275 | 0.015 | 0 | 100% | |
| 305 | 0.024 | -0.001 | 104% | |
| 335 | 0.034 | 0 | 100% | |
| 365 | 0.048 | 0.001 | 98% | |
| 390 | 0.061 | 0.003 | 95% | |
| 410 | 0.07 | 0.003 | 96% | |
| 430 | 0.086 | 0.005 | 94% | |
| 455 | 0.1 | 0.01 | 90% | |

Table 2S. Purine/Pyrimidine Biosynthesis - Oligonucleotide #63

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|------------------|-------------|---------|--|
| Time T=0 | Control 0.002 | 63 0.004 | † Inhib | |
| 0 | 0 | 0 | | |
| 60 | 0.001 | 0.001 | 0% | |
| 120 | 0.001 | 0.002 | -100% | |
| 180 | 0.001 | 0.001 | 0% | |
| 240 | 0.005 | 0.002 | 60% | |
| 285 | 0.012 | 0.001 | 92% | |
| 350 | 0.027 | -0.001 | 104% | |
| 390 | 0.043 | 0.001 | 98% | |
| 420 | 0.063 | 0.002 | 97% | |
| 450 | 0.082 | 0.001 | 99% | |
| 470 | 0.096 | 0.004 | 96% | |
| 500 | 0.106 | 0.008 | 92% | |

Table 2T. Outer Membrane Proteins - Oligonucleotide #78

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|------------------|-------------|---------|--|
| Time T=0 | Control 0.001 | 78 0.004 | † Inhib | |
| 0 | 0 | 0 | | |
| 60 | 0.001 | -0.002 | 300% | |
| 120 | 0.002 | -0.002 | 200% | |
| 165 | 0.005 | -0.003 | 160% | |
| 210 | 0.015 | -0.004 | 127% | |
| 255 | 0.025 | -0.004 | 116% | |
| 285 | 0.041 | -0.003 | 107% | |
| 315 | 0.058 | -0.003 | 105% | |
| 335 | 0.073 | -0.002 | 103% | |
| 355 | 0.089 | -0.002 | 102% | |
| 375 | 0.101 | -0.002 | 102% | |

Table 2U. Nitrate Reductase - Oligonucleotide #71

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|-------|---------|
| Time T=0 | Control | 71 | 0.002 | % Inhib |
| 0 | 0 | 0 | 0 | |
| 105 | 0.002 | 0 | 100% | |
| 175 | 0.003 | -0.002 | 167% | |
| 220 | 0.004 | -0.001 | 125% | |
| 270 | 0.007 | -0.001 | 114% | |
| 300 | 0.012 | -0.001 | 108% | |
| 330 | 0.022 | -0.001 | 105% | |
| 360 | 0.032 | 0 | 100% | |
| 395 | 0.052 | 0 | 100% | |
| 425 | 0.065 | 0.003 | 95% | |
| 445 | 0.081 | 0.004 | 95% | |
| 465 | 0.09 | 0.006 | 93% | |
| 490 | 0.108 | 0.013 | 88% | |

Table 2V. Drug Resistance - Oligonucleotide #114

| Escherichia coli 35218 Multiple Drug Resistance | | | | |
|--|---------|--------|-------|---------|
| Time T=0 | Control | 114 | 0.006 | % Inhib |
| 0 | 0 | 0 | 0 | |
| 105 | 0.002 | -0.002 | 200% | |
| 175 | 0.003 | -0.005 | 267% | |
| 220 | 0.004 | -0.003 | 175% | |
| 270 | 0.007 | -0.003 | 143% | |
| 300 | 0.012 | -0.004 | 133% | |
| 330 | 0.022 | -0.004 | 118% | |
| 360 | 0.032 | -0.004 | 113% | |
| 395 | 0.052 | -0.004 | 108% | |
| 425 | 0.065 | -0.003 | 105% | |
| 445 | 0.081 | -0.001 | 101% | |
| 465 | 0.09 | 0 | 100% | |
| 490 | 0.108 | 0.004 | 96% | |

Table 2W. Vitamin Metabolism - Oligonucleotide #5

| Escherichia coli 35218 Multiple Drug Resistance | | | |
|--|-------------------|------------|---------|
| Time T=0 | Control -0.001 | 5 0.002 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.001 | 200% |
| 150 | 0.002 | -0.003 | 250% |
| 195 | 0.005 | -0.002 | 140% |
| 245 | 0.013 | -0.001 | 108% |
| 275 | 0.019 | 0 | 100% |
| 320 | 0.04 | 0 | 100% |
| 350 | 0.054 | -0.001 | 102% |
| 365 | 0.066 | 0 | 100% |
| 385 | 0.079 | 0 | 100% |
| 415 | 0.095 | -0.001 | 101% |
| 430 | 0.105 | 0.001 | 99% |

Table 3A.

| Escherichia coli 35218 Multiple Drug Resistance | | | | | | | |
|--|--------------|------------|--------|------------|--------|------------|--------|
| Time T=0 | Control 0 | A 0.003 | %Inhib | B 0.006 | %Inhib | C 0.003 | %Inhib |
| 0 | 0 | 0 | | 0 | | 0 | |
| 60 | 0.001 | -0.001 | 200% | -0.004 | 500% | -0.002 | 300% |
| 105 | 0.002 | -0.002 | 200% | -0.004 | 300% | -0.002 | 200% |
| 145 | 0.002 | -0.001 | 150% | -0.003 | 250% | -0.002 | 200% |
| 190 | 0.002 | -0.001 | 150% | -0.003 | 250% | -0.002 | 200% |
| 230 | 0.005 | -0.001 | 120% | -0.003 | 160% | -0.002 | 140% |
| 275 | 0.009 | -0.001 | 111% | -0.003 | 133% | -0.003 | 133% |
| 320 | 0.015 | -0.002 | 113% | -0.002 | 113% | -0.003 | 120% |
| 350 | 0.022 | -0.001 | 105% | -0.001 | 105% | -0.003 | 114% |
| 380 | 0.030 | 0 | 100% | -0.001 | 103% | -0.002 | 107% |
| 410 | 0.048 | 0.001 | 98% | -0.001 | 102% | -0.003 | 106% |
| 445 | 0.068 | 0.005 | 93% | -0.003 | 104% | -0.003 | 104% |
| 465 | 0.08 | 0.009 | 89% | -0.002 | 103% | -0.003 | 104% |
| 485 | 0.097 | 0.015 | 85% | 0.002 | 98% | -0.003 | 103% |

A=2'-O-Me version 18

B=12mer version 18

35 C=15mer version 18

Table 3B.

| Escherichia coli 35218 Multiple Drug Resistance | | | | | |
|--|---------|--------|--------|--------|--------|
| Time T=0 | Control | D | %Inhib | E | %Inhib |
| | 0 | 0 | 0.002 | 0.006 | |
| 0 | 0 | 0 | 0 | 0 | |
| 60 | 0.001 | -0.001 | 200% | -0.004 | 500% |
| 105 | 0.002 | -0.001 | 150% | -0.004 | 300% |
| 145 | 0.002 | -0.001 | 150% | -0.005 | 350% |
| 190 | 0.002 | -0.001 | 150% | -0.002 | 200% |
| 230 | 0.005 | -0.001 | 120% | -0.004 | 180% |
| 275 | 0.009 | -0.001 | 111% | -0.004 | 144% |
| 320 | 0.015 | -0.001 | 107% | -0.004 | 127% |
| 350 | 0.022 | -0.001 | 105% | -0.003 | 114% |
| 380 | 0.03 | -0.001 | 103% | -0.003 | 110% |
| 410 | 0.048 | -0.001 | 102% | -0.003 | 106% |
| 445 | 0.068 | -0.001 | 101% | -0.001 | 101% |
| 465 | 0.08 | -0.001 | 101% | -0.001 | 101% |
| 485 | 0.097 | -0.001 | 101% | 0.002 | 98% |

D=5' amino group/15mer version 18

E=33mer version 18

Table 3C.

| Staphylococcus aureus 13301 | | | | | | |
|-----------------------------|---------|-------|--------|--------|--------|-----|
| Time T=0 | Control | A | %Inhib | B | %Inhib | C |
| | 0 | 0 | 0 | -0.001 | 0.001 | |
| 0 | 0 | 0 | 0 | 0 | 0 | |
| 90 | 0.003 | 0.002 | 33% | 0.003 | 0% | 0% |
| 150 | 0.003 | 0.001 | 67% | 0.004 | -33% | 0% |
| 210 | 0.005 | 0.002 | 60% | 0.004 | 20% | 40% |
| 270 | 0.006 | 0.001 | 83% | 0.003 | 50% | 50% |
| 325 | 0.014 | 0.001 | 93% | 0.002 | 86% | 79% |
| 380 | 0.032 | 0.002 | 94% | 0.003 | 91% | 94% |
| 410 | 0.044 | 0.003 | 93% | 0.003 | 93% | 93% |
| 440 | 0.057 | 0.004 | 93% | 0.003 | 95% | 95% |
| 470 | 0.075 | 0.005 | 93% | 0.021 | 72% | 96% |
| 500 | 0.105 | 0.011 | 90% | 0.004 | 96% | 96% |

A=2'-O-Me version 18

B=pEthoxy version 18

C=12mer version 18

Table 3D.

| Staphylococcus aureus 13301 | | | | | |
|-----------------------------|---------|-------|--------|-------|--------|
| Time | Control | D | %Inhib | E | %Inhib |
| T=0 | 0.001 | 0.003 | 0.003 | 0.003 | |
| 0 | 0 | 0 | 0 | 0 | |
| 5 | 65 | 0.001 | 0.001 | 0% | -200% |
| | 125 | 0.002 | 0.003 | -50% | -50% |
| | 185 | 0.003 | 0.002 | 33% | -33% |
| | 240 | 0.003 | 0.002 | 33% | -33% |
| 10 | 295 | 0.004 | 0.002 | 50% | 25% |
| | 340 | 0.007 | 0.003 | 57% | 14% |
| | 385 | 0.011 | 0.003 | 73% | 55% |
| | 415 | 0.016 | 0.002 | 88% | 75% |
| 15 | 445 | 0.021 | 0.002 | 90% | 81% |
| | 475 | 0.032 | 0.002 | 94% | 88% |
| | 505 | 0.029 | 0.002 | 93% | 83% |
| | 535 | 0.045 | 0.002 | 96% | 87% |
| | 565 | 0.057 | 0.002 | 96% | 91% |
| | 595 | 0.072 | 0.002 | 97% | 88% |
| | 625 | 0.09 | 0.002 | 98% | 93% |
| | | | | | |

D=15mer version 18

E=18mer version 18

25

30

35

Table 4A.

| Salmonella typhimurium | | | | | | | | | |
|------------------------|-------------------|-------------|--------|-------------|--------|-------------|--------|-------------|--------|
| Time T=0 | Control -0.001 | 18 0.004 | %Inhib | 39 0.004 | %Inhib | 63 0.003 | %Inhib | 78 0.002 | %Inhib |
| 0 | 0 | 0 | | 0 | | 0 | | 0 | |
| 90 | 0.001 | -0.001 | 200% | -0.002 | 300% | -0.002 | 300% | -0.001 | 200% |
| 150 | 0.002 | -0.004 | 300% | -0.002 | 200% | -0.001 | 150% | -0.001 | 150% |
| 210 | 0.003 | -0.004 | 233% | -0.002 | 167% | -0.001 | 133% | -0.001 | 133% |
| 260 | 0.006 | -0.001 | 117% | -0.001 | 117% | -0.001 | 117% | -0.001 | 117% |
| 325 | 0.020 | | 100% | -0.001 | 105% | -0.001 | 105% | 0.001 | 95% |
| 360 | 0.033 | 0.002 | 94% | 0.001 | 97% | 0.002 | 94% | 0.003 | 91% |
| 390 | 0.049 | 0.007 | 86% | 0.005 | 90% | 0.004 | 92% | 0.007 | 86% |
| 420 | 0.067 | 0.012 | 82% | 0.01 | 85% | 0.007 | 90% | 0.012 | 82% |
| 445 | 0.093 | 0.019 | 80% | 0.016 | 83% | 0.011 | 88% | 0.019 | 80% |
| 460 | 0.103 | 0.023 | 78% | 0.02 | 81% | 0.015 | 85% | 0.024 | 77% |

15

Table 4B.

| Salmonella typhimurium | | | |
|------------------------|------------------|-------------|--------|
| Time T=0 | Control 0.005 | 73 0.008 | %Inhib |
| 0 | 0 | | 0 |
| 60 | -0.001 | -0.001 | |
| 120 | 0.001 | -0.001 | 200% |
| 165 | 0.003 | -0.003 | 200% |
| 230 | 0.009 | -0.004 | 144% |
| 260 | 0.013 | -0.004 | 131% |
| 295 | 0.024 | -0.003 | 113% |
| 325 | 0.037 | -0.002 | 105% |
| 350 | 0.051 | -0.004 | 108% |
| 370 | 0.066 | -0.003 | 105% |
| 390 | 0.082 | 0 | 100% |
| 410 | 0.098 | -0.002 | 102% |
| 430 | 0.112 | 0 | 100% |

35

Table 4C.

| <i>Pseudomonas aeruginosa</i> | | | | | | |
|-------------------------------|---------|-------|--------|-------|--------|-------|
| Time | Control | 39 | %Inhib | 63 | %Inhib | 78 |
| T=0 | 0.002 | 0.005 | | 0.007 | | 0.005 |
| 0 | 0 | 0 | | 0 | | 0 |
| 5 | 90 | 0.001 | -0.001 | 200% | 0 | 100% |
| | 190 | 0.002 | 0 | 100% | -0.001 | 150% |
| | 250 | 0.003 | -0.001 | 133% | -0.002 | 167% |
| | 300 | 0.004 | -0.001 | 125% | -0.002 | 150% |
| | 345 | 0.004 | 0 | 100% | 0 | 100% |
| 10 | 375 | 0.005 | 0.001 | 80% | 0.001 | 80% |
| | 415 | 0.008 | 0.003 | 63% | 0.004 | 50% |
| | 465 | 0.013 | 0.008 | 38% | 0.007 | 46% |
| | 505 | 0.02 | 0.013 | 35% | 0.013 | 35% |
| | 545 | 0.036 | 0.022 | 39% | 0.022 | 39% |
| | | 0.051 | 0.038 | 25% | 0.034 | 33% |
| 15 | 600 | 0.072 | 0.055 | 24% | 0.052 | 28% |

Table 4D.

| <i>Pseudomonas aeruginosa</i> | | | | | |
|-------------------------------|---------|-------|--------|-------|--------|
| Time | Control | 82 | %Inhib | 114 | %Inhib |
| T=0 | 0 | 0.004 | | 0.002 | |
| 0 | 0 | 0 | | 0 | |
| 20 | 90 | 0.002 | 0.001 | 50% | 0.001 |
| | 120 | 0.003 | 0.002 | 33% | 0.003 |
| | 180 | 0.006 | 0.003 | 50% | 0.004 |
| 25 | 240 | 0.007 | 0.004 | 43% | 0.004 |
| | 305 | 0.019 | 0.012 | 37% | 0.011 |
| | 335 | 0.024 | 0.017 | 29% | 0.019 |
| | 365 | 0.036 | 0.027 | 25% | 0.028 |
| | 400 | 0.062 | 0.05 | 19% | 0.049 |
| 30 | 420 | 0.074 | 0.061 | 18% | 0.06 |
| | 440 | 0.086 | 0.074 | 14% | 0.071 |
| | 460 | 0.103 | 0.091 | 12% | 0.087 |

Table 4E.

| <i>Klebsiella pneumoniae</i> | | | | | | | |
|------------------------------|---------|--------|--------|--------|--------|---------|--------|
| Time | Control | 114 | %Inhib | 78 | %Inhib | 73 | %Inhib |
| T=0 | 0.006 | 0.008 | | 0.006 | | 0.008 | |
| 0 | 0 | -0.001 | | 0 | | 0 | |
| 60 | -0.002 | -0.002 | | -0.001 | | -0.002 | |
| 120 | 0 | -0.003 | | -0.001 | | -0.0074 | |
| 165 | 0.004 | -0.004 | 200% | -0.003 | 175% | -0.003 | 175% |
| 230 | 0.011 | -0.004 | 136% | -0.001 | 109% | -0.003 | 127% |
| 260 | 0.019 | -0.004 | 121% | 0 | 100% | -0.003 | 116% |
| 295 | 0.036 | -0.003 | 108% | 0.003 | 92% | -0.003 | 108% |
| 325 | 0.051 | -0.001 | 102% | 0.007 | 86% | -0.003 | 106% |
| 350 | 0.064 | 0 | 100% | 0.012 | 81% | -0.003 | 105% |
| 370 | 0.074 | 0.002 | 97% | 0.018 | 76% | -0.003 | 104% |
| 390 | 0.088 | 0.006 | 93% | 0.025 | 72% | -0.003 | 103% |
| 410 | 0.098 | 0.01 | 90% | 0.037 | 62% | -0.003 | 103% |

Table 4F.

| <i>Klebsiella pneumoniae</i> | | | | | |
|------------------------------|---------|--------|--------|--------|--------|
| Time | Control | 71 | %Inhib | 111 | %Inhib |
| T=0 | 0.006 | 0.009 | | 0.008 | |
| 0 | 0 | 0 | | 0 | |
| 60 | -0.001 | -0.003 | | -0.002 | |
| 135 | 0.005 | 0 | 100% | -0.002 | 200% |
| 180 | 0.012 | 0 | 100% | 0 | 100% |
| 210 | 0.019 | 0.004 | 79% | 0.002 | 83% |
| 240 | 0.03 | 0.006 | 80% | 0.006 | 67% |
| 270 | 0.05 | 0.014 | 72% | 0.012 | 63% |
| 315 | 0.072 | 0.03 | 58% | 0.024 | 54% |
| 335 | 0.083 | 0.039 | 53% | 0.032 | 54% |
| 355 | 0.107 | 0.051 | 52% | 0.041 | 51% |

Table 4G.

| Yersinia mollaretii | | | | | | |
|---------------------|------------------|------------|----------------------|------------------------|------------------------|------------------------|
| Time T=0 | Control 0.003 | 2 0.002 | %Inhib 4 0.002 | %Inhib 127 0.002 | %Inhib 127 0.002 | %Inhib 127 0.002 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 90 | 0.001 | 0.001 | 0% | 0.001 | 0% | 0% |
| 155 | 0.002 | 0.002 | 0% | 0.002 | 0% | 0% |
| 200 | 0.004 | 0.003 | 25% | 0.003 | 25% | 25% |
| 255 | 0.008 | 0.003 | 63% | 0.003 | 63% | 50% |
| 285 | 0.01 | 0.004 | 60% | 0.004 | 60% | 40% |
| 10 320 | 0.014 | 0.008 | 43% | 0.008 | 43% | 14% |
| 350 | 0.023 | 0.012 | 48% | 0.013 | 43% | 22% |
| 380 | 0.029 | 0.018 | 38% | 0.018 | 38% | 14% |
| 410 | 0.039 | 0.026 | 33% | 0.027 | 31% | 10% |
| 440 | 0.054 | 0.035 | 35% | 0.036 | 33% | 11% |
| 470 | 0.075 | 0.05 | 33% | 0.056 | 25% | 5% |
| 15 500 | 0.096 | 0.07 | 27% | 0.071 | 26% | 9% |
| 505 | 0.101 | 0.072 | 29% | 0.075 | 26% | 9% |

Table 4H.

| Yersinia mollaretii | | | | |
|---------------------|------------------|-------------|-----------------------|-----------------------|
| Time T=0 | Control 0.002 | 63 0.004 | %Inhib 73 0.004 | %Inhib 73 0.004 |
| 0 | 0 | 0 | 0 | 0 |
| 20 90 | 0.001 | 0.002 | -100% | 100% |
| 25 190 | 0.002 | 0.003 | -50% | 50% |
| 250 | 0.003 | 0.003 | 0% | 67% |
| 300 | 0.003 | 0 | 100% | 67% |
| 345 | 0.006 | 0.003 | 50% | 50% |
| 375 | 0.008 | 0.005 | 38% | 38% |
| 415 | 0.013 | 0.008 | 38% | 31% |
| 30 465 | 0.023 | 0.018 | 22% | 17% |
| 505 | 0.031 | 0.027 | 13% | 18% |
| 545 | 0.055 | 0.043 | 22% | 22% |
| 575 | 0.074 | 0.065 | 12% | 14% |
| 605 | 0.093 | 0.083 | 11% | 14% |
| 35 615 | 0.103 | 0.089 | 14% | 15% |

Table 4I.

Table 4I.

Neisseria sicca

| Time T=0 | Pos. Control OD | 16 | %Inhib | 12 | %Inhib | 20 | %Inhib |
|-------------|-----------------------|--------|--------|--------|--------|--------|--------|
| | 0.029 | 0.064 | | 0.035 | | 0.084 | |
| 0 | 0 | 0 | | 0 | | 0 | |
| 30 | 0.002 | -0.003 | | -0.002 | | -0.002 | |
| 65 | 0.002 | -0.003 | | -0.003 | | -0.004 | |
| 125 | 0.006 | -0.001 | 117% | -0.002 | 133% | -0.002 | 133% |
| 150 | 0.01 | 0.001 | 90% | 0 | 100% | -0.002 | 120% |
| 180 | 0.014 | 0.001 | 93% | 0.002 | 86% | -0.001 | 107% |
| 240 | 0.023 | 0 | 100% | 0.002 | 91% | -0.003 | 113% |
| 300 | 0.029 | 0.01 | 66% | 0.009 | 69% | 0.006 | 79% |
| 330 | 0.029 | 0.014 | 52% | 0.013 | 55% | 0.012 | 59% |
| 390 | 0.033 | 0.014 | 58% | 0.009 | 73% | 0.012 | 64% |
| 450 | 0.031 | 0.004 | 87% | 0.009 | 71% | 0.003 | 90% |
| 490 | 0.036 | 0.014 | 61% | 0.008 | 78% | 0.008 | 78% |
| 520 | 0.038 | 0.015 | 61% | 0.014 | 63% | 0.011 | 71% |
| 560 | 0.049 | 0.013 | 73% | 0.002 | 96% | 0.007 | 86% |
| 590 | 0.052 | 0.017 | 67% | 0.014 | 73% | 0.012 | 77% |
| 620 | 0.057 | 0.018 | 68% | 0.014 | 75% | 0.014 | 75% |
| 650 | 0.059 | 0.016 | 73% | 0.018 | 69% | 0.014 | 76% |
| 680 | 0.063 | 0.018 | 71% | 0.016 | 75% | 0.016 | 75% |
| 710 | 0.068 | 0.019 | 72% | 0.017 | 75% | 0.016 | 76% |

Table 4J.

| Neisseria sicca | | | | | |
|-----------------|-----------------------------|--------|--------|--------|--------|
| Time T=0 | Pos. Control OD 0.029 | 3 | %Inhib | 15 | %Inhib |
| | | 0.018 | | 0.056 | |
| 0 | 0 | 0 | | 0 | |
| 30 | 0.002 | -0.001 | | 0.001 | |
| 65 | 0.002 | -0.004 | | 0 | |
| 125 | 0.006 | -0.001 | 117% | 0.002 | 67% |
| 150 | 0.01 | 0.004 | 60% | -0.003 | 130% |
| 180 | 0.014 | 0.005 | 64% | -0.002 | 114% |
| 240 | 0.025 | 0.004 | 84% | -0.003 | 112% |
| 300 | 0.027 | 0.008 | 70% | 0.01 | 63% |
| 330 | 0.029 | 0.015 | 48% | 0.018 | 38% |
| 390 | 0.033 | 0.012 | 64% | -0.003 | 109% |
| 450 | 0.031 | 0.005 | 84% | 0.01 | 68% |
| 490 | 0.036 | 0.012 | 67% | 0.016 | 56% |
| 520 | 0.038 | 0.007 | 82% | 0.018 | 53% |
| 560 | 0.049 | 0.011 | 78% | 0.021 | 57% |
| 590 | 0.052 | 0.011 | 79% | 0.02 | 62% |
| 620 | 0.057 | 0.011 | 81% | 0.018 | 68% |
| 650 | 0.059 | 0.012 | 80% | 0.018 | 69% |
| 680 | 0.063 | 0.011 | 83% | 0.02 | 68% |
| 710 | 0.068 | 0.012 | 82% | 0.17 | 75% |

Table 4K.

| Serratia liquefaciens | | | | | | | |
|-----------------------|-------------------|--------|--------|-------|--------|-------|--------|
| Time T=0 | Control -0.001 | 2 | %Inhib | 39 | %Inhib | 82 | %Inhib |
| | | -0.001 | | 0.001 | | 0.002 | |
| 0 | 0 | 0 | | 0 | | 0 | |
| 110 | 0.002 | 0.002 | 0% | 0.002 | 0% | 100% | 0% |
| 180 | 0.003 | 0.003 | 0% | 0.001 | 67% | 0.001 | 67% |
| 240 | 0.003 | 0.002 | 33% | 0.001 | 67% | 0.001 | 67% |
| 300 | 0.002 | 0.002 | 0% | 0.001 | 50% | 0 | 100% |
| 360 | 0.005 | 0.002 | 60% | 0.001 | 80% | 0 | 100% |
| 420 | 0.011 | 0.003 | 73% | 0.001 | 91% | 0.001 | 91% |
| 475 | 0.022 | 0.003 | 86% | 0.002 | 91% | 0.001 | 95% |
| 520 | 0.041 | 0.003 | 93% | 0.001 | 98% | 0.001 | 98% |
| 610 | 0.082 | 0.003 | 96% | 0.001 | 99% | 0.001 | 99% |
| 655 | 0.1 | 0.003 | 97% | 0.001 | 99% | 0.001 | 99% |

Table 4L.

| Streptococcus mutans | | | | | | |
|----------------------|------------------|------------|--------|-------------|--------|--------------|
| Time T=0 | Control 0.184 | 1 0.187 | %Inhib | 89 0.187 | %Inhib | 127 0.187 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 60 | 0.001 | -0.003 | 400% | -0.001 | 200% | -0.002 |
| 115 | 0.006 | -0.001 | 117% | 0.003 | 50% | 0.001 |
| 145 | 0.011 | -0.001 | 109% | 0.003 | 73% | 0.003 |
| 180 | 0.016 | 0.002 | 88% | 0.008 | 50% | 0.006 |
| 210 | 0.022 | 0.004 | 82% | 0.01 | 55% | 0.008 |
| 10 245 | 0.031 | 0.009 | 71% | 0.015 | 52% | 0.014 |
| 290 | 0.047 | 0.015 | 68% | 0.021 | 55% | 0.021 |
| 320 | 0.059 | 0.022 | 63% | 0.026 | 56% | 0.03 |
| 350 | 0.071 | 0.03 | 58% | 0.032 | 55% | 0.04 |
| 385 | 0.082 | 0.036 | 56% | 0.032 | 61% | 0.047 |
| 415 | 0.097 | 0.042 | 57% | 0.036 | 63% | 0.05 |
| 15 445 | 0.109 | 0.045 | 59% | 0.039 | 64% | 0.063 |

Table 4M.

| Streptococcus mutans | | | | |
|----------------------|------------------|--------------|--------|--------------|
| Time T=0 | Control 0.184 | 132 0.187 | %Inhib | 114 0.183 |
| 0 | 0 | 0 | 0 | 0 |
| 20 60 | 0.001 | -0.002 | 300% | -0.003 |
| 115 | 0.006 | 0.001 | 83% | -0.001 |
| 145 | 0.011 | 0.001 | 91% | 0.002 |
| 25 180 | 0.016 | 0.006 | 63% | 0.004 |
| 210 | 0.022 | 0.008 | 64% | 0.008 |
| 245 | 0.031 | 0.01 | 68% | 0.013 |
| 290 | 0.047 | 0.017 | 64% | 0.025 |
| 320 | 0.059 | 0.022 | 63% | 0.034 |
| 30 350 | 0.071 | 0.027 | 62% | 0.045 |
| 385 | 0.082 | 0.028 | 66% | 0.054 |
| 415 | 0.097 | 0.033 | 66% | 0.062 |
| 445 | 0.109 | 0.034 | 69% | 0.069 |

Table 4N.

| Streptococcus pyogenes | | | | | | |
|------------------------|------------------|------------|--------------|--------|---------------|--------|
| Time T=0 | Control 0.177 | 1 0.179 | %Inhib 89 | 0.177 | %Inhib 127 | 0.179 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 110 | 0.001 | 0 | 100% | -0.001 | 200% | -0.004 |
| 170 | 0.003 | -0.002 | 167% | -0.002 | 167% | -0.005 |
| 210 | 0.005 | -0.001 | 120% | 0 | 100% | -0.003 |
| 240 | 0.008 | -0.001 | 113% | -0.001 | 113% | -0.002 |
| 300 | 0.01 | 0 | 100% | 0.001 | 90% | 0 |
| 10 345 | 0.014 | 0.003 | 79% | 0.002 | 86% | 0 |
| 390 | 0.021 | 0.006 | 71% | 0.003 | 86% | 0 |
| 450 | 0.036 | 0.01 | 72% | 0.008 | 78% | 0.007 |
| 510 | 0.067 | 0.017 | 75% | 0.015 | 78% | 0.015 |
| 540 | 0.093 | 0.025 | 73% | 0.026 | 72% | 0.025 |
| 15 555 | 0.107 | 0.028 | 74% | 0.029 | 73% | 0.025 |

Table 4O.

| Streptococcus pyogenes | | | | | |
|------------------------|------------------|--------------|---------------|--------|--------|
| Time T=0 | Control 0.177 | 132 0.177 | %Inhib 114 | 0.181 | %Inhib |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 20 110 | 0.001 | -0.001 | 200% | -0.001 | 133% |
| 170 | 0.003 | -0.003 | 200% | -0.003 | 175% |
| 25 210 | 0.005 | 0 | 100% | -0.004 | 200% |
| 240 | 0.008 | -0.001 | 113% | -0.001 | 117% |
| 300 | 0.01 | 0.001 | 90% | 0 | 100% |
| 345 | 0.014 | 0.002 | 86% | 0.001 | 91% |
| 390 | 0.021 | 0.004 | 81% | 0.005 | 69% |
| 450 | 0.036 | 0.009 | 75% | 0.015 | 55% |
| 30 510 | 0.067 | 0.015 | 78% | 0.031 | 47% |
| 540 | 0.093 | 0.021 | 77% | 0.047 | 45% |
| 555 | 0.107 | 0.021 | 80% | 0.053 | 48% |

Table 4P.

| Shigella | | | | | |
|-------------|------------------|-----------------|------------------|-------------------|--|
| Time T=0 | Control 0.001 | 1 0.003 %Inh | 89 0.003 %Inh | 127 0.004 %Inh | |
| 0 | 0 | 0 | 0 | 0 | |
| 95 | 0.001 | -0.001 200% | -0.001 200% | -0.001 200% | |
| 155 | 0.005 | -0.001 120% | -0.003 160% | -0.002 140% | |
| 215 | 0.009 | -0.001 111% | -0.002 122% | -0.002 122% | |
| 275 | 0.027 | 0 100% | -0.002 107% | -0.001 104% | |
| 305 | 0.038 | 0 100% | -0.003 108% | -0.002 105% | |
| 335 | 0.044 | 0.001 98% | -0.001 102% | -0.003 107% | |
| 365 | 0.047 | 0.004 91% | -0.002 104% | -0.001 102% | |
| 395 | 0.051 | 0.006 88% | -0.002 104% | -0.001 102% | |
| 425 | 0.051 | 0.008 84% | -0.003 106% | -0.001 102% | |

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Table 4Q.

| Shigella | | | | |
|-------------|------------------|-------------------|-------------------|--|
| Time T=0 | Control 0.001 | 132 0.003 %Inh | 114 0.003 %Inh | |
| 0 | 0 | 0 | 0 | |
| 95 | 0.001 | -0.001 200% | -0.001 200% | |
| 155 | 0.005 | -0.001 120% | -0.002 140% | |
| 215 | 0.009 | -0.001 111% | -0.003 133% | |
| 275 | 0.027 | -0.001 104% | -0.003 111% | |
| 305 | 0.038 | -0.002 105% | -0.003 108% | |
| 335 | 0.044 | -0.003 107% | -0.003 107% | |
| 365 | 0.047 | -0.001 102% | -0.003 106% | |
| 395 | 0.051 | 0 100% | -0.002 104% | |
| 425 | 0.051 | 0 100% | -0.002 104% | |

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Table 4R.

| <i>Haemophilus</i> | | | |
|--------------------|------------------|-------------|------|
| Time T=0 | Control 0.161 | 78 0.017 | %Inh |
| 0 | 0 | 0 | |
| 70 | 0.007 | 0 | 100% |
| 140 | 0.012 | 0.008 | 33% |
| 190 | 0.013 | 0.01 | 23% |
| 235 | 0.013 | 0.013 | 0% |
| 275 | 0.013 | 0.013 | 0% |
| 305 | 0.015 | 0.012 | 20% |
| 365 | 0.016 | 0.013 | 19% |
| 24' | 0.026 | 0.011 | 58% |
| 29' 50' | 0.051 | 0.014 | 73% |
| 46' | 0.241 | 0.021 | 91% |

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Table 4S.

Table 43.

| Mycobacterium | | | | | | | |
|---------------|------------------|--------------|------|-------------|------|-------------|------|
| Time T=0 | Control 0.167 | 114 0.163 | %Inh | 10 0.168 | %Inh | 21 0.165 | %Inh |
| 0 | 0 | 0 | | 0 | | 0 | |
| 90 | 0.006 | 0.001 | 83% | 0.001 | 83% | 0.002 | 67% |
| 120 | 0.009 | 0.003 | 67% | 0.002 | 78% | 0.006 | 33% |
| 165 | 0.014 | 0.005 | 64% | 0.005 | 64% | 0.01 | 29% |
| 195 | 0.021 | 0.006 | 71% | 0.005 | 76% | 0.008 | 62% |
| 240 | 0.021 | 0.007 | 67% | 0.007 | 67% | 0.009 | 57% |
| 270 | 0.018 | 0.013 | 28% | 0.01 | 44% | 0.013 | 28% |
| 305 | 0.028 | 0.016 | 43% | 0.012 | 57% | 0.014 | 50% |
| 405 | 0.04 | 0.026 | 35% | 0.032 | 20% | 0.025 | 38% |
| 465 | 0.051 | 0.032 | 37% | 0.041 | 20% | 0.032 | 37% |
| 525 | 0.063 | 0.04 | 37% | 0.051 | 19% | 0.043 | 32% |
| 555 | 0.073 | 0.046 | 37% | 0.06 | 18% | 0.052 | 29% |
| 585 | 0.08 | 0.051 | 36% | 0.065 | 19% | 0.055 | 31% |
| 615 | 0.085 | 0.062 | 27% | 0.073 | 14% | 0.062 | 27% |
| 645 | 0.097 | 0.065 | 33% | 0.079 | 19% | 0.068 | 30% |

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Table 4T.

| <i>Mycobacterium</i> | | | | | |
|----------------------|------------------|-------------|------|-------------|------|
| Time T=0 | Control 0.167 | 18 0.163 | %Inh | 78 0.166 | %Inh |
| 0 | 0 | 0 | | 0 | |
| 90 | 0.006 | -0.001 | 117% | 0 | 100% |
| 120 | 0.009 | 0.002 | 78% | 0.003 | 67% |
| 165 | 0.014 | 0.007 | 50% | 0.003 | 79% |
| 195 | 0.021 | 0.006 | 71% | 0.004 | 81% |
| 240 | 0.021 | 0.008 | 62% | 0.006 | 71% |
| 270 | 0.018 | 0.008 | 56% | 0.003 | 83% |
| 305 | 0.028 | 0.01 | 64% | 0.009 | 68% |
| 405 | 0.04 | 0.022 | 45% | 0.018 | 55% |
| 465 | 0.051 | 0.03 | 41% | 0.024 | 53% |
| 525 | 0.063 | 0.037 | 41% | 0.029 | 54% |
| 555 | 0.073 | 0.044 | 40% | 0.037 | 49% |
| 585 | 0.08 | 0.047 | 41% | 0.04 | 50% |
| 615 | 0.085 | 0.052 | 39% | 0.042 | 51% |
| 645 | 0.097 | 0.059 | 39% | 0.056 | 42% |

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Table 4U.

| <i>Helicobacter</i> | | | |
|---------------------|-----------------|-------------|------|
| Time T=0 | Control 0.08 | 78 0.084 | %Inh |
| 0 | 0 | 0 | |
| 70 | -0.004 | -0.009 | |
| 140 | 0 | -0.006 | |
| 190 | 0.001 | -0.005 | 600% |
| 235 | 0.003 | -0.001 | 133% |
| 275 | 0.004 | 0 | 100% |
| 305 | 0.009 | 0.004 | 56% |
| 365 | 0.01 | 0.003 | 70% |
| 24' | 0.057 | 0.01 | 82% |
| 29' 50' | 0.065 | 0.012 | 82% |
| 45' | 0.065 | 0.005 | 92% |

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Table 4V.

| Enterococcus | | | | | |
|--------------|-----------------|------------------|-------------------|-------------------|--------------------|
| Time T=0 | Control 0.09 | 89 0.088 %Inh | 127 0.087 %Inh | 132 0.088 %Inh | p127 0.086 %Inh |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 0 | -0.004 | -0.006 | -0.006 | -0.007 |
| 105 | 0.005 | -0.004 180% | -0.002 140% | -0.003 160% | -0.005 200% |
| 150 | 0.026 | 0.008 69% | 0.009 65% | 0.008 69% | 0.01 62% |
| 170 | 0.066 | 0.029 56% | 0.029 56% | 0.025 62% | 0.032 52% |
| 195 | 0.076 | 0.04 47% | 0.04 47% | 0.036 53% | 0.043 43% |
| 210 | 0.091 | 0.051 44% | 0.052 43% | 0.047 48% | 0.054 41% |
| 215 | 0.11 | 0.062 44% | 0.064 42% | 0.055 50% | 0.066 40% |

Table 4W.

| Enterococcus | | | |
|--------------|------------------|-----------------|------------------|
| Time T=0 | Control 0.042 | 1 0.049 %Inh | 76 0.049 %Inh |
| 0 | 0 | 0 | 0 |
| 60 | 0.002 | -0.002 200% | -0.001 150% |
| 120 | 0.006 | -0.001 117% | 0 100% |
| 160 | 0.023 | 0.002 91% | 0.003 87% |
| 190 | 0.036 | 0.01 72% | 0.013 64% |
| 210 | 0.051 | 0.015 71% | 0.02 61% |
| 230 | 0.074 | 0.031 58% | 0.04 46% |
| 245 | 0.083 | 0.037 55% | 0.046 45% |
| 255 | 0.094 | 0.047 50% | 0.057 39% |
| 265 | 0.109 | 0.054 50% | 0.065 40% |

Table 4X.

| Streptococcus pneumonia | | | | | |
|-------------------------|-----------------|-------------|-------------|-------------|--|
| Time T=0 | Control 0.17 | 1 0.172 | 79 0.174 | 114 0.17 | |
| 0 | 0 | 0 | 0 | 0 | |
| 5 | | | | | |
| 60 | 0.004 | 0 100% | 0 100% | -0.001 125% | |
| 110 | 0.003 | -0.005 267% | -0.001 133% | -0.001 133% | |
| 170 | 0.003 | -0.003 200% | -0.001 133% | -0.001 133% | |
| 220 | 0.004 | -0.002 150% | 0 100% | -0.001 125% | |
| 260 | 0.004 | -0.001 125% | -0.001 125% | -0.001 125% | |
| 10 | | | | | |
| 310 | 0.007 | -0.002 129% | 0 100% | -0.001 114% | |
| 370 | 0.008 | -0.003 138% | 0 100% | 0 100% | |
| 445 | 0.009 | -0.002 122% | 0 100% | 0 100% | |
| 485 | 0.009 | -0.003 133% | 0.001 89% | 0.001 89% | |
| 15 | | | | | |
| 19'35' | 0.014 | 0.001 93% | 0.011 21% | 0.008 43% | |
| 21'35' | 0.014 | 0.001 93% | 0.01 29% | 0.006 57% | |
| 23'35' | 0.015 | 0.002 87% | 0.012 20% | 0.008 47% | |
| 27' | 0.016 | 0.001 94% | 0.013 19% | 0.009 44% | |
| 28'30' | 0.016 | 0.002 88% | 0.014 12% | 0.01 38% | |
| 45'20' | 0.023 | 0.018 22% | 0.024 -4% | 0.018 22% | |
| 48'20' | 0.024 | 0.008 67% | 0.025 -4% | 0.014 42% | |
| 20 | | | | | |
| 51'20' | 0.024 | 0.01 58% | 0.035 -46% | 0.022 8% | |
| 54'20' | 0.026 | 0.011 58% | 0.028 -8% | 0.021 19% | |
| 70'35' | 0.035 | 0.014 60% | 0.033 6% | 0.027 23% | |
| 95'35' | 0.05 | 0.025 50% | 0.059 -18% | 0.04 20% | |
| 101' | 0.068 | 0.025 63% | 0.046 32% | 0.043 37% | |

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Table 4Y.

| Streptococcus pneumonia | | | | | |
|-------------------------|-----------------|--------------|------|--------------|------|
| Time T=0 | Control 0.17 | 127 0.172 | %Inh | 132 0.167 | %Inh |
| 0 | 0 | 0 | | 0 | |
| 5 | | | | | |
| 60 | 0.004 | -0.001 | 125% | -0.001 | 125% |
| 110 | 0.003 | -0.001 | 133% | -0.003 | 200% |
| 170 | 0.003 | -0.002 | 167% | -0.003 | 200% |
| 220 | 0.004 | -0.002 | 150% | -0.002 | 150% |
| 260 | 0.004 | -0.001 | 125% | -0.002 | 150% |
| 10 | | | | | |
| 310 | 0.007 | -0.002 | 129% | -0.001 | 114% |
| 370 | 0.008 | 0 | 100% | 0 | 100% |
| 445 | 0.009 | 0 | 100% | 0 | 100% |
| 485 | 0.009 | 0 | 100% | 0 | 100% |
| 15 | | | | | |
| 19'35' | 0.014 | 0.008 | 43% | 0.009 | 36% |
| 21'35' | 0.014 | 0.007 | 50% | 0.009 | 36% |
| 23'35' | 0.015 | 0.008 | 47% | 0.009 | 40% |
| 27' | 0.016 | 0.01 | 37% | 0.013 | 19% |
| 28'30' | 0.016 | 0.012 | 25% | 0.012 | 25% |
| 45'20' | 0.023 | 0.019 | 17% | 0.022 | 4% |
| 48'20' | 0.024 | 0.2 | 17% | 0.021 | 13% |
| 20 | | | | | |
| 51'20' | 0.024 | 0.021 | 12% | 0.022 | 8% |
| 54'20' | 0.026 | 0.022 | 15% | 0.024 | 8% |
| 70'35' | 0.035 | 0.027 | 23% | 0.033 | 6% |
| 95'35' | 0.05 | 0.048 | 4% | 0.05 | 0% |
| 101' | 0.068 | 0.048 | 29% | 0.052 | 24% |

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Table 4Z.

| Vibrio | | | | | |
|-------------|------------------|-------------|------|--------------|------|
| Time T=0 | Control 0.138 | 78 0.142 | %Inh | 127 0.143 | %Inh |
| 0 | 0 | 0 | | 0 | |
| 5 70 | 0.002 | -0.001 | 150% | -0.003 | 250% |
| 140 | 0.002 | 0 | 100% | -0.002 | 200% |
| 190 | 0.005 | 0 | 100% | 0 | 100% |
| 235 | 0.005 | 0.001 | 80% | -0.002 | 140% |
| 275 | 0.005 | 0.001 | 80% | -0.003 | 160% |
| 10 305 | 0.005 | 0 | 100% | 0 | 100% |
| 365 | 0.004 | -0.001 | 125% | -0.002 | 150% |
| 24' | 0.006 | 0.003 | 50% | 0 | 100% |
| 46' | 0.177 | 0.006 | 97% | 0.129 | 27% |

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Table 5A.

| Staphylococcus aureus 13301 | | | | | | |
|-----------------------------|------------------|-------------|--------|-------------|--------|-------------|
| Time T=0 | Control 0.001 | 21 0.004 | %Inhib | 68 0.002 | %Inhib | 85 0.002 |
| 0 | 0 | 0 | | 0 | | 0 |
| 5 | | | | | | |
| 65 | 0.001 | 0.001 | 0% | 0.002 | -100% | 0.001 |
| 125 | 0.002 | 0.002 | 0% | 0.003 | -50% | 0.002 |
| 185 | 0.003 | 0.002 | 33% | 0.003 | 0% | 0.003 |
| 240 | 0.003 | 0.002 | 33% | 0.003 | 0% | 0.002 |
| 295 | 0.004 | 0.001 | 75% | 0.003 | 25% | 0.002 |
| 10 | | | | | | |
| 340 | 0.007 | 0.002 | 71% | 0.003 | 57% | 0.003 |
| 385 | 0.011 | 0.004 | 64% | 0.003 | 73% | 0.002 |
| 415 | 0.016 | 0.002 | 88% | 0.003 | 81% | 0.001 |
| 445 | 0.021 | 0.002 | 90% | 0.003 | 86% | 0.002 |
| 475 | 0.032 | 0.002 | 94% | 0.003 | 91% | 0.002 |
| 15 | | | | | | |
| 505 | 0.029 | 0.001 | 97% | 0.003 | 90% | 0.002 |
| 535 | 0.045 | 0.001 | 98% | 0.003 | 93% | 0.002 |
| 565 | 0.057 | 0 | 100% | 0.001 | 98% | 0.003 |
| 595 | 0.072 | 0.002 | 97% | 0.003 | 96% | 0.003 |
| 625 | 0.09 | 0.002 | 98% | 0.002 | 98% | 0.002 |
| 25' | 0.456 | -0.002 | 100% | 0 | 100% | 0.026 |

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Table 5B.

| Staphylococcus aureus 13301 | | | | | | |
|-----------------------------|------------------|--------------|--------|-------------|--------|------|
| Time T=0 | Control 0.001 | 112 0.005 | %Inhib | 18 0.003 | %Inhib | |
| 0 | 0 | 0 | | 0 | | |
| 5 | 65 | 0.0010 | 100% | 0.001 | 0% | |
| | 125 | 0.002 | 0.002 | 0% | 0.003 | -50% |
| | 185 | 0.003 | 0.001 | 67% | 0.002 | 33% |
| | 240 | 0.003 | 0.001 | 67% | 0.002 | 33% |
| | 295 | 0.004 | 0.002 | 50% | 0.002 | 50% |
| 10 | 340 | 0.007 | 0.001 | 86% | 0.003 | 57% |
| | 385 | 0.011 | 0.001 | 91% | 0.003 | 73% |
| | 415 | 0.016 | 0 | 100% | 0.002 | 88% |
| | 445 | 0.021 | 0 | 100% | 0.002 | 90% |
| | 475 | 0.032 | 0.001 | 97% | 0.002 | 94% |
| 15 | 505 | 0.029 | 0.001 | 97% | 0.002 | 93% |
| | 535 | 0.045 | 0.002 | 96% | 0.002 | 96% |
| | 565 | 0.057 | 0.002 | 96% | 0.002 | 96% |
| | 595 | 0.072 | 0.001 | 99% | 0.002 | 97% |
| | 625 | 0.09 | 0 | 100% | 0.002 | 98% |
| 25' | 0.456 | -0.003 | 101% | 0 | 100% | |

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Table 5C.

| Table 5C. <i>Escherichia coli</i> 35218 Multiple Drug Resistance | | | | | | | |
|--|------------------|-------------|--------|-------------|--------|-------------|--------|
| Time T=0 | Control 0.001 | 21 0.004 | %Inhib | 68 0.005 | %Inhib | 85 0.005 | %Inhib |
| 0 | 0 | 0 | | 0.001 | | 0.001 | |
| 70 | 0.002 | 0.001 | 50% | -0.002 | 200% | -0.001 | 150% |
| 130 | 0.002 | 0.001 | 50% | -0.001 | 150% | -0.001 | 150% |
| 190 | 0.002 | -0.001 | 150% | -0.003 | 250% | -0.002 | 200% |
| 250 | 0.009 | -0.002 | 122% | -0.003 | 133% | -0.003 | 133% |
| 295 | 0.015 | -0.002 | 113% | -0.002 | 113% | -0.002 | 113% |
| 325 | 0.024 | -0.001 | 104% | -0.002 | 108% | -0.002 | 108% |
| 355 | 0.032 | -0.002 | 106% | -0.002 | 106% | -0.002 | 106% |
| 385 | 0.046 | -0.002 | 104% | -0.003 | 107% | -0.002 | 104% |
| 415 | 0.068 | -0.001 | 101% | -0.002 | 103% | -0.002 | 103% |
| 445 | 0.087 | -0.001 | 101% | -0.001 | 101% | -0.001 | 101% |
| 465 | 0.1 | -0.001 | 101% | -0.001 | 101% | -0.002 | 102% |
| 555 | 0.138 | 0.009 | 93% | 0.01 | 93% | 0.005 | 96% |
| 27' | 0.191 | 0.196 | -3% | 0.192 | -1% | 0.192 | -1% |

Table 5D.

| Table SD. | | | | | |
|--|------------------|--------------|--------|-------------|-------------|
| Escherichia coli 35218 Multiple Drug Resistance | | | | | |
| Time T=0 | Control 0.001 | 112 0.004 | %Inhib | 18 0.003 | %Inhib |
| 5 | 0 | 0 | -0.002 | 0 | |
| | 70 | 0.002 | -0.004 | 300% | -0.001 150% |
| | 130 | 0.002 | -0.005 | 350% | -0.001 150% |
| | 190 | 0.002 | -0.005 | 350% | -0.001 150% |
| | 250 | 0.009 | -0.005 | 156% | -0.001 111% |
| | 295 | 0.015 | -0.004 | 127% | 0 100% |
| 10 | 325 | 0.024 | -0.004 | 117% | -0.001 104% |
| | 355 | 0.032 | -0.005 | 116% | 0 100% |
| | 385 | 0.046 | -0.004 | 109% | -0.001 102% |
| | 415 | 0.068 | -0.004 | 106% | 0 100% |
| | 445 | 0.087 | -0.003 | 103% | 0.003 97% |
| 15 | 465 | 0.1 | -0.004 | 104% | 0.004 96% |
| | 555 | 0.138 | 0.008 | 94% | 0.026 81% |
| | 27' | 0.191 | 0.178 | 7% | 0.174 9% |

Table 5E.

Table 5E.

Escherichia coli 25922

NBT89

At different concentrations

| Time T=0 | Control C | 2.1mg 0.004 | %Inh | 1.05mg 0.003 | %Inh | 0.525mg 0.002 | %Inh |
|-------------|--------------|----------------|------|-----------------|------|------------------|------|
| | C | 0 | | 0 | | 0 | |
| 5 | 0.001 | -0.001 | 200% | -0.001 | 200% | -0.001 | 200% |
| 12 | 0.001 | -0.002 | 300% | -0.001 | 222% | -0.001 | 200% |
| 22 | 0.005 | -0.002 | 140% | -0.001 | 120% | -0.001 | 120% |
| 27 | 0.012 | -0.001 | 108% | -0.001 | 108% | -0.001 | 108% |
| 31 | 0.027 | -0.001 | 104% | -0.001 | 104% | 0 | 100% |
| 33 | 0.035 | -0.001 | 103% | -0.001 | 103% | 0.001 | 97% |
| 35 | 0.044 | -0.002 | 105% | -0.001 | 102% | 0.002 | 95% |
| 37 | 0.052 | -0.002 | 104% | -0.001 | 102% | 0.002 | 96% |
| 39 | 0.06 | -0.003 | 105% | -0.001 | 102% | 0.002 | 97% |
| 41 | 0.081 | -0.002 | 102% | -0.001 | 101% | 0.003 | 96% |
| 43 | 0.092 | -0.002 | 102% | -0.001 | 101% | 0.005 | 95% |
| 44 | 0.101 | -0.002 | 102% | 0.000 | 100% | 0.009 | 91% |
| 24 hr | | | 27% | | 18% | | 16% |

Table 5F.

| Table 5F. | | | | | | | | | |
|--|---------|------------------|--------|--------------|--------|-----------------|--------|------------------|--------|
| Escherichia coli 25922 NBT89 At different concentrations | | | | | | | | | |
| Time T=0 | Control | 0.265mg 0.003 | %Inhib | 0.133mg 0 | %Inhib | 0.07mg 0.002 | %Inhib | 0.035mg 0.001 | %Inhib |
| C | 0 | 0 | | 0 | | 0 | | 0 | |
| 60 | 0.001 | -0.001 | 200% | 0 | 100% | 0 | 100% | 0 | 100% |
| 120 | 0.001 | -0.001 | 200% | 0 | 100% | -0.001 | 100% | 0 | 100% |
| 225 | 0.005 | -0.001 | 120% | 0 | 100% | 0.001 | 30% | 0.002 | 60% |
| 270 | 0.012 | -0.001 | 108% | 0.001 | 75% | 0.004 | 57% | 0.006 | 50% |
| 315 | 0.027 | 0.003 | 89% | 0.01 | 33% | 0.012 | 53% | 0.015 | 44% |
| 335 | 0.035 | 0.004 | 89% | 0.015 | 57% | 0.018 | 49% | 0.022 | 37% |
| 355 | 0.044 | 0.006 | 86% | 0.021 | 52% | 0.024 | 45% | 0.029 | 34% |
| 375 | 0.052 | 0.008 | 85% | 0.025 | 52% | 0.029 | 44% | 0.035 | 33% |
| 395 | 0.06 | 0.012 | 80% | 0.032 | 47% | 0.037 | 33% | 0.044 | 27% |
| 415 | 0.081 | 0.018 | 78% | 0.044 | 46% | 0.052 | 36% | 0.061 | 25% |
| 430 | 0.092 | 0.021 | 77% | 0.054 | 41% | 0.063 | 32% | 0.072 | 22% |
| 445 | 0.101 | 0.028 | 72% | 0.064 | 37% | 0.071 | 28% | 0.082 | 19% |
| 24 hr | | | 14% | | 11% | | 15% | | 11% |

Table 6A
The Effects of Oligonucleotide Purification Method
on the Percent Inhibition of *Escherichia coli* 35218
(See Section 5.5.)

| Time | Control | A | B | C | D | E |
|--------|---------|------|------|------|------|------|
| 0 | 0 | | | | | |
| 5 90 | .003 | 100% | 100% | 100% | 100% | 100% |
| 150 | .004 | 100% | 100% | 100% | 100% | 100% |
| 220 | .008 | 75% | 100% | 100% | 63% | 100% |
| 270 | .014 | 36% | 100% | 100% | 14% | 100% |
| 315 | .029 | 38% | 100% | 100% | 10% | 100% |
| 10 345 | .038 | 21% | 100% | 100% | 8% | 100% |
| 375 | .059 | 25% | 93% | 97% | 3% | 100% |
| 400 | .079 | 27% | 90% | 90% | 6% | 99% |
| 420 | .089 | 25% | 84% | 84% | 5% | 98% |
| 435 | .099 | 24% | 83% | 83% | 6% | 96% |

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Table 6B
The Effects of Oligonucleotide Purification Method
on the Percent Inhibition of *Escherichia coli* 35218
(See Section 5.5.)

| Time | Control | F | G | H | I |
|--------|---------|------|------|------|------|
| 20 0 | 0 | | | | |
| 90 | .003 | 100% | 100% | 100% | 100% |
| 150 | .004 | 100% | 100% | 100% | 100% |
| 220 | .008 | 100% | 100% | 100% | 100% |
| 270 | .014 | 100% | 100% | 100% | 100% |
| 25 315 | .029 | 63% | 100% | 100% | 100% |
| 345 | .038 | 47% | 100% | 100% | 100% |
| 375 | .059 | 50% | 100% | 98% | 100% |
| 400 | .079 | 34% | 96% | 91% | 100% |
| 420 | .089 | 43% | 96% | 88% | 100% |
| 435 | .099 | 41% | 93% | 86% | 100% |

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Table 7
Antigene Oligonucleotides Targeted to DNA sense strand
for Triplex Formation

| Escherichia coli 35218 Multiple Drug Resistance | | | | | |
|--|------------------|----------------|--------|----------------|--------|
| Time T=0 | Control 0.002 | 96.SS 0.008 | %Inhib | 73.SS 0.004 | %Inhib |
| 0 | 0 | 0.004 | | 0 | |
| 60 | 0.001 | 0 | 100% | 0.001 | 0% |
| 120 | 0.001 | 0 | 100% | 0 | 100% |
| 180 | 0.001 | 0 | 100% | -0.001 | 200% |
| 240 | 0.005 | -0.001 | 120% | 0 | 100% |
| 285 | 0.012 | -0.001 | 108% | -0.002 | 117% |
| 350 | 0.027 | -0.001 | 104% | 0 | 100% |
| 390 | 0.043 | 0.002 | 95% | 0.001 | 98% |
| 420 | 0.063 | 0.006 | 90% | 0.004 | 94% |
| 450 | 0.082 | 0.01 | 88% | 0.008 | 90% |
| 470 | 0.096 | 0.017 | 82% | 0.01 | 90% |
| 500 | 0.106 | 0.023 | 78% | 0.012 | 89% |

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Table 8A.

| Escherichia coli 11370 Streptomycin Resistant | | | |
|--|---------|--------|--------|
| Time T=0 | Control | 73 | %Inhib |
| | 0 | 0.004 | |
| 0 | 0 | 0 | |
| 60 | 0.005 | 0 | 100% |
| 140 | 0.011 | -0.002 | 118% |
| 170 | 0.013 | 0 | 100% |
| 215 | 0.021 | 0.003 | 86% |
| 245 | 0.032 | 0.005 | 84% |
| 275 | 0.045 | 0.007 | 84% |
| 305 | 0.062 | 0.009 | 85% |
| 325 | 0.076 | 0.009 | 88% |
| 340 | 0.09 | 0.01 | 89% |
| 350 | 0.1 | 0.012 | 88% |

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Table 8B.

| Escherichia coli 29214 Sulfonamide Resistant | | | |
|---|---------|--------|--------|
| Time T=0 | Control | 73 | %Inhib |
| | 0.001 | 0.003 | |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.002 | 300% |
| 130 | 0.005 | -0.001 | 120% |
| 175 | 0.015 | -0.001 | 107% |
| 205 | 0.022 | -0.001 | 105% |
| 235 | 0.031 | -0.001 | 103% |
| 270 | 0.05 | 0 | 100% |
| 295 | 0.065 | 0 | 100% |
| 315 | 0.081 | 0.003 | 96% |
| 335 | 0.092 | 0.006 | 93% |

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Table 8C.

| Escherichia coli 25922 Intermediate Penicillin Resistant | | | |
|---|------------------|-------------|--------|
| Time T=0 | Control 0.004 | 73 0.006 | %Inhib |
| 0 | 0 | 0 | |
| 60 | -0.001 | -0.001 | |
| 120 | 0 | -0.001 | |
| 165 | 0 | -0.001 | |
| 230 | 0.003 | -0.001 | 133% |
| 260 | 0.005 | -0.002 | 140% |
| 305 | 0.014 | -0.002 | 114% |
| 335 | 0.021 | -0.002 | 110% |
| 365 | 0.033 | -0.002 | 106% |
| 395 | 0.052 | -0.001 | 102% |
| 415 | 0.066 | -0.002 | 103% |
| 435 | 0.08 | -0.002 | 103% |
| 455 | 0.093 | -0.002 | 102% |
| 475 | 0.108 | -0.001 | 101% |

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Table 8D.

| Salmonella typhimurium 23564 | | | |
|------------------------------|------------------|-------------|--------|
| Time T=0 | Control 0.005 | 73 0.008 | %Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.001 | |
| 120 | 0.001 | -0.001 | 200% |
| 165 | 0.003 | -0.003 | 200% |
| 230 | 0.009 | -0.004 | 144% |
| 260 | 0.013 | -0.004 | 131% |
| 295 | 0.024 | -0.003 | 113% |
| 325 | 0.037 | -0.002 | 105% |
| 350 | 0.051 | -0.004 | 108% |
| 370 | 0.066 | -0.003 | 105% |
| 390 | 0.082 | 0 | 100% |
| 410 | 0.098 | -0.002 | 102% |

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Table 8E.

| Klebsiella pneumoniae 4352 | | | |
|----------------------------|------------------|-------------|--------|
| Time T=0 | Control 0.006 | 73 0.008 | %Inhib |
| 0 | 0 | 0 | |
| 5 60 | -0.002 | -0.002 | |
| 120 | 0 | -0.0074 | |
| 165 | 0.004 | -0.003 | 175% |
| 230 | 0.011 | -0.003 | 127% |
| 260 | 0.019 | -0.003 | 116% |
| 10 295 | 0.036 | -0.003 | 108% |
| 325 | 0.051 | -0.003 | 106% |
| 350 | 0.064 | -0.003 | 105% |
| 370 | 0.074 | -0.003 | 104% |
| 390 | 0.088 | -0.003 | 103% |
| 15 410 | 0.098 | -0.003 | 103% |

Table 8F.

| Escherichia coli 35218 Multiple Drug Resistance | | | |
|--|------------------|--------------|--------|
| Time T=0 | Control 0.001 | 73 -0.004 | %Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.003 | 400% |
| 25 120 | 0.003 | -0.002 | 167% |
| 180 | 0.013 | -0.001 | 108% |
| 210 | 0.019 | -0.002 | 111% |
| 240 | 0.027 | -0.001 | 104% |
| 270 | 0.04 | 0 | 100% |
| 300 | 0.058 | 0.003 | 95% |
| 30 320 | 0.075 | 0.006 | 92% |
| 340 | 0.089 | 0.008 | 91% |
| 355 | 0.103 | 0.013 | 87% |

Table 8G.

| Staphylococcus aureus 29213 | | | |
|-----------------------------|---------|--------|--------|
| Time T=0 | Control | 73 | %Inhib |
| | 0 | -0.007 | |
| 0 | 0 | 0 | |
| 5 60 | 0 | -0.003 | |
| 120 | 0.003 | -0.004 | 233% |
| 165 | 0.006 | -0.003 | 150% |
| 210 | 0.01 | 0.001 | 90% |
| 240 | 0.014 | 0.004 | 71% |
| 10 270 | 0.024 | 0.011 | 54% |
| 300 | 0.034 | 0.021 | 38% |
| 340 | 0.48 | 0.033 | 31% |
| 360 | 0.06 | 0.041 | 32% |
| 380 | 0.072 | 0.05 | 31% |
| 400 | 0.09 | 0.062 | 31% |
| 15 420 | 0.102 | 0.07 | 31% |

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Tables 9 (A-G)
Oligonucleotide NBT 114 vs. Different Strains of Bacteria

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Table 9A.

| Escherichia coli 11370 Streptomycin Resistant | | | |
|--|--------------|--------------|---------|
| Time T=0 | Control 0 | 114 0.004 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0.005 | -0.003 | 160% |
| 140 | 0.011 | 0 | 100% |
| 170 | 0.013 | 0.003 | 77% |
| 215 | 0.021 | 0.009 | 57% |
| 245 | 0.032 | 0.014 | 56% |
| 275 | 0.045 | 0.018 | 60% |
| 305 | 0.062 | 0.024 | 61% |
| 325 | 0.076 | 0.03 | 61% |
| 340 | 0.09 | 0.034 | 62% |
| 350 | 0.1 | 0.036 | 64% |

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Table 9B.

| Escherichia coli 29214 Sulfonamide Resistant | | | |
|---|------------------|--------------|---------|
| Time T=0 | Control 0.001 | 114 0.003 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.002 | 300% |
| 130 | 0.005 | -0.001 | 120% |
| 175 | 0.015 | -0.001 | 107% |
| 205 | 0.022 | -0.001 | 105% |
| 235 | 0.031 | 0 | 100% |
| 270 | 0.05 | 0.005 | 90% |
| 295 | 0.065 | 0.007 | 89% |
| 315 | 0.081 | 0.012 | 85% |
| 335 | 0.092 | 0.017 | 82% |

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Table 9C.

| Escherichia coli 25922 Intermediate Penicillin Resistant | | | |
|---|------------------|--------------|---------|
| Time T=0 | Control 0.004 | 114 0.008 | % Inhib |
| 0 | 0 | 0 | |
| 60 | -0.001 | 0 | |
| 120 | 0 | -0.002 | |
| 165 | 0 | -0.004 | |
| 230 | 0.003 | -0.004 | 233% |
| 260 | 0.005 | -0.004 | 180% |
| 305 | 0.014 | -0.002 | 114% |
| 335 | 0.021 | 0 | 100% |
| 365 | 0.033 | 0.001 | 97% |
| 395 | 0.052 | 0.007 | 87% |
| 415 | 0.066 | 0.012 | 82% |
| 435 | 0.08 | 0.018 | 78% |
| 455 | 0.093 | 0.026 | 72% |
| 475 | 0.108 | 0.035 | 88% |

Table 9D.

| Salmonella typhimurium 23564 | | | |
|------------------------------|------------------|--------------|---------|
| Time T=0 | Control 0.005 | 114 0.007 | % Inhib |
| 0 | 0 | 0 | |
| 60 | -0.001 | 0 | |
| 120 | 0.001 | -0.001 | 200% |
| 165 | 0.003 | -0.003 | 200% |
| 230 | 0.009 | -0.003 | 133% |
| 260 | 0.013 | -0.002 | 115% |
| 295 | 0.024 | 0 | 100% |
| 325 | 0.037 | 0.003 | 92% |
| 350 | 0.051 | 0.009 | 82% |
| 370 | 0.066 | 0.012 | 82% |
| 390 | 0.082 | 0.017 | 79% |
| 410 | 0.098 | 0.024 | 76% |

Table 9E.

| <i>Klebsiella pneumoniae</i> 4352 | | | |
|-----------------------------------|------------------|--------------|---------|
| Time T=0 | Control 0.006 | 114 0.008 | % Inhib |
| 0 | 0 | -0.001 | |
| 60 | -0.002 | -0.002 | |
| 120 | 0 | -0.003 | |
| 165 | 0.004 | -0.004 | 200% |
| 230 | 0.011 | -0.004 | 136% |
| 260 | 0.019 | -0.004 | 121% |
| 295 | 0.036 | -0.003 | 108% |
| 325 | 0.051 | -0.001 | 102% |
| 350 | 0.064 | 0 | 100% |
| 370 | 0.074 | 0.002 | 97% |
| 390 | 0.088 | 0.006 | 93% |
| 410 | 0.098 | 0.01 | 90% |

Table 9F.

| <i>Escherichia coli</i> 35218 Multiple Drug Resistance | | | |
|---|------------------|--------------|---------|
| Time T=0 | Control 0.001 | 114 0.003 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0.001 | -0.002 | 300% |
| 120 | 0.003 | -0.001 | 133% |
| 180 | 0.013 | 0 | 100% |
| 210 | 0.019 | 0 | 100% |
| 240 | 0.027 | 0.002 | 93% |
| 270 | 0.04 | 0.006 | 85% |
| 300 | 0.058 | 0.014 | 76% |
| 320 | 0.075 | 0.023 | 69% |
| 340 | 0.089 | 0.031 | 65% |
| 355 | 0.103 | 0.04 | 61% |

Table 9G.

| Staphylococcus aureus 29213 | | | |
|-----------------------------|--------------|--------------|---------|
| Time T=0 | Control 0 | 114 0.005 | % Inhib |
| 0 | 0 | 0 | |
| 60 | 0 | -0.003 | |
| 120 | 0.003 | -0.003 | 200% |
| 165 | 0.006 | -0.002 | 133% |
| 210 | 0.01 | 0.002 | 80% |
| 240 | 0.014 | 0.005 | 64% |
| 270 | 0.024 | 0.012 | 50% |
| 300 | 0.034 | 0.019 | 44% |
| 340 | 0.048 | 0.031 | 35% |
| 360 | 0.06 | 0.039 | 35% |
| 380 | 0.072 | 0.047 | 35% |
| 400 | 0.09 | 0.058 | 36% |
| 420 | 0.102 | 0.063 | 38% |

Table 10

| Restoration of Ampicillin Sensitivity in an Ampicillin Resistant Strain of Escherichia coli Y1088 | | | | | |
|--|--------------------------|----------------------------------|--------------------------|-----------------------------------|-----|
| Time T=0 | Control +50 μg/ml amp | NBT 14 +50μg/ml amp %Inhib | Control +250μg/ml amp | NBT 14 +250μg/ml amp %Inhib | |
| 0 | 0 | 0 | 0 | 0 | |
| 60 | 0 | 0 | 0 | 0 | |
| 120 | 0 | 0 | 0 | 0 | |
| 180 | 0 | 0 | 0 | 0 | |
| 245 | 0 | 0 | 0.002 | 0 | |
| 270 | 0 | 0 | 0.004 | 0.001 | 75% |
| 290 | 0.001 | 0.001 | 0.006 | 0.002 | 67% |
| 310 | 0.006 | 0.002 | 0.007 | 0.002 | 71% |
| 330 | 0.007 | 0.003 | 0.013 | 0.004 | 69% |
| 355 | 0.013 | 0.005 | 0.02 | 0.006 | 70% |
| 370 | 0.017 | 0.007 | 0.022 | 0.008 | 64% |
| 390 | 0.026 | 0.011 | 0.03 | 0.013 | 57% |
| 410 | 0.032 | 0.016 | 0.039 | 0.018 | 54% |
| 430 | 0.038 | 0.021 | 0.043 | 0.023 | 46% |
| 450 | 0.052 | 0.026 | 0.062 | 0.031 | 50% |
| 470 | 0.069 | 0.035 | 0.075 | 0.041 | 45% |

Table 11

Number of Bacteria in the blood

| | T=0 | T=24 hr. | Change over 24 hours |
|----------------|--------------------------|-----------------------------|-------------------------------|
| Saline Control | 1×10^8 bacteria | 3×10^8 bacteria | 3 fold increase in bacteria |
| +Oligo NBT 132 | 1×10^8 bacteria | 0.13×10^8 bacteria | 10 fold reduction in bacteria |

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What is claimed is:

1. A method for treating an animal, including a human, having an infection caused by a pathogenic bacterium, comprising: administering to the animal a composition
5 comprising a pharmaceutically acceptable carrier and a substantially nuclease resistant oligonucleotide having about 8 to about 80 nucleotides and targeted to a nucleic acid or protein in the bacterium in an amount sufficient to alleviate a symptom of the infection.
- 10 2. The method of claim 1, wherein the nucleic acid or protein is involved in the synthesis, metabolism, assembly or regulation of at least one of the group consisting of energy, DNA replication, cell division, regulatory proteins, cell walls, sugars, virulence, fatty acids, mRNAs, tRNAs, rRNAs,
15 ribosomal proteins, proteins involved in protein synthesis, phospholipids, periplasmic proteins, secretory proteins, flagellar proteins, transport proteins, amino acids, lipopolysaccharides, purines, pyrimidines, pili, outer membrane proteins, nitrogen, antibiotic binding proteins and
20 vitamins.
3. The method of claim 1, wherein the oligonucleotide is capable of associating with a nucleic acid or protein in the bacterium such that it inhibits at least one of the group consisting of bacterial growth, reproduction, metabolism,
25 synthesis of toxins, progress of infection and virulence.
4. The method of claim 3, wherein the associating is hybridizing to an mRNA in the bacterium at or near the initiation codon, in the 5' untranslated region, in the 3' untranslated region, internal to the coding region or an
30 intermediate region of the mRNA.
5. The method of claim 3, wherein the associating is hybridizing to DNA in the bacterium.
6. The method of claim 5, wherein the hybridizing forms a triplex structure.
- 35 7. The method of claim 3, wherein the associating is binding with a protein in the bacterium.

8. The method of claim 1, wherein the oligonucleotide hybridizes to any one of the operons listed in Table 1.

9. The method of claim 1, wherein the oligonucleotide hybridizes to any one of the genes listed in Table 1.

5 10. The method of claim 1, wherein the oligonucleotide comprises a sequence drawn from SEQ ID NOS. 1-176 of the Sequence Listing or a functional equivalent thereof.

11. The method of claim 1, wherein the oligonucleotide has been purified by a method comprising at least one method
10 from the group consisting of diafiltration, gel filtration, high performance liquid chromatography, fast performance liquid chromatography, alcohol precipitations, or alcohol extractions followed by ethanol or chloroform extractions.

12. The method of claim 1, wherein the oligonucleotide
15 was purified by gel filtration.

13. The method of claim 1, wherein the oligonucleotide is capable of inhibiting growth of the bacterium in an MIC assay.

14. The method of claim 1, wherein the oligonucleotide
20 has been modified in at least one base, sugar or internucleotide linkage so as to increase nuclease resistance, stability, specificity or uptake by bacteria of the oligonucleotide.

15. The method of claim 1, wherein the oligonucleotide
25 is selected from at least one of the group consisting of:

a) partially or fully substituted phosphorothioate oligonucleotides or analogues thereof;

b) partially or fully substituted alkyl phosphonate oligonucleotides or analogues thereof;

30 c) partially or fully substituted phosphate ester oligonucleotides or analogues thereof;

d) partially or fully substituted phosphoramidate oligonucleotides or analogues thereof;

35 e) partially or fully substituted 2' modified RNA oligonucleotides or analogues thereof;

f) partially or fully substituted morpholino oligonucleotides or analogues thereof;

- g) partially or fully substituted peptide nucleic acid oligonucleotides or analogues thereof;
- h) partially or fully substituted dithioate oligonucleotides or analogues thereof;
- 5 i) partially or fully substituted 5' thio oligonucleotides or analogues thereof;
- j) partially or fully substituted propyne oligonucleotides or analogues thereof;
- k) chimerics of any combination of the above; and
- 10 l) any chemical modifications of the oligonucleotide which leave the oligonucleotide capable of specifically binding the nucleic acid or protein.
16. The method of claim 1, wherein the administration is selected from the group consisting of oral, intravenous, 15 intramuscular, intraperitoneal, subcutaneous, intradermal, inhalation and topical administration.
17. The method of claim 1, wherein the bacterium is gram positive.
18. The method of claim 1, wherein the bacterium is 20 gram negative.
19. The method of claim 1, wherein the bacterium is acid fast.
20. The method of claim 1, wherein the bacterium is a member of a genus selected from the group consisting of 25 *Aerococcus*, *Listeria*, *Streptomyces*, *Actinomadura*, *Lactobacillus*, *Eubacterium*, *Arachnia*, *Mycobacterium*, *Peptostreptococcus*, *Staphylococcus*, *Corynebacterium*, *Erysipelothrix*, *Dermatophilus*, *Rhodococcus*, *Bifodobacterium*, *Lactobacillus*, *Streptococcus*, *Bacillus*, *Peptococcus*, 30 *Micrococcus*, *Kurthia*, *Nocardia*, *Nocardiosis*, *Rothia*, *Propionibacterium*, *Actinomyces*, *Enterococcus*, *Pneumococcus*, and *Clostridia*.
21. The method of claim 1, wherein the bacterium is a member of the genus *Staphylococcus*.
- 35 22. The method of claim 21, wherein the bacterium is *Staphylococcus aureus*.

23. The method of claim 1, wherein the bacterium is a member of the genus *Pseudomonas*.
24. The method of claim 1, wherein the bacterium is a member of the genus *Klebsiella*.
- 5 25. The method of claim 1, wherein the bacterium is a member of the genus *Yersinia*.
26. The method of claim 1, wherein the bacterium is a member of the genus *Neisseria*.
27. The method of claim 1, wherein the bacterium is a
10 member of the genus *Serratia*.
28. The method of claim 1, wherein the bacterium is a member of the genus *Streptococcus*.
29. The method of claim 28, wherein the bacterium is *Streptococcus pyogenes*.
- 15 30. The method of claim 28, wherein the bacterium is *Streptococcus pneumoniae*.
31. The method of claim 1, wherein the bacterium is a member of the genus *Shigella*.
32. The method of claim 1, wherein the bacterium is a
20 member of the genus *Haemophilus*.
33. The method of claim 1, wherein the bacterium is a member of the genus *Mycobacterium*.
34. The method of claim 1, wherein the bacterium is a member of the genus *Helicobacter*.
- 25 35. The method of claim 1, wherein the bacterium is a member of the genus *Enterococcus*.
36. The method of claim 1, wherein the bacterium is a member of the genus *Vibrio*.
37. The method of claim 1, wherein the bacterium is a
30 member of the genus *Salmonella*.
38. The method of claim 1, wherein the bacterium is a *Pneumococcus*.
39. The method of claim 1, wherein the bacterium is *Escherichia coli*.
- 35 40. A composition comprising a pharmaceutically acceptable carrier and a substantially nuclease resistant oligonucleotide having about 8 to about 80 nucleotides and

targeted to a nucleic acid or protein in the bacterium in an amount sufficient to alleviate a symptom of the infection.

41. The composition of claim 40, wherein the nucleic acid or protein is involved in the synthesis, metabolism, 5 assembly or regulation of at least one of the group consisting of energy, DNA replication, cell division, regulatory proteins, cell walls, sugars, virulence, fatty acids, mRNAs, tRNAs, rRNAs, ribosomal proteins, proteins involved in protein synthesis, phospholipids, periplasmic 10 proteins, secretory proteins, flagellar proteins, transport proteins, amino acids, lipopolysaccharides, purines, pyrimidines, pili, outer membrane proteins, nitrogen, antibiotic binding proteins and vitamins.

42. The composition of claim 40, wherein the 15 oligonucleotide is capable of associating with a nucleic acid or protein in the bacterium such that it inhibits at least one of the group consisting of bacterial growth, reproduction, metabolism, synthesis of toxins, progress of infection and virulence.

20 43. The composition of claim 42, wherein the associating is hybridizing to an mRNA in the bacterium at or near the initiation codon, in the 5' untranslated region, in the 3' untranslated region, internal to the coding region or an intermediate region of the mRNA.

25 44. The composition of claim 42, wherein the associating is hybridizing to DNA in the bacterium.

45. The composition of claim 44, wherein the hybridizing forms a triplex structure.

30 46. The composition of claim 42, wherein the associating is binding with a protein in the bacterium.

47. The composition of claim 40, wherein the oligonucleotide hybridizes to any one of the operons listed in Table 1.

35 48. The composition of claim 40, wherein the oligonucleotide hybridizes to any one of the genes listed in Table 1.

49. The composition of claim 40, wherein the oligonucleotide comprises a sequence drawn from SEQ ID NOS. 1-176 of the Sequence Listing or a functional equivalent thereof.

5 50. The composition of claim 40, wherein the oligonucleotide has been purified by a method comprising at least one method from the group consisting of diafiltration, gel filtration, high performance liquid chromatography, fast performance liquid chromatography, alcohol precipitations or
10 alcohol extractions followed by ethanol or chloroform extractions.

51. The composition of claim 40, wherein the oligonucleotide was purified by gel filtration.

52. The composition of claim 40, wherein the
15 oligonucleotide is capable of inhibiting growth of the bacterium in an MIC assay.

53. The composition of claim 40, wherein the oligonucleotide has been modified in at least one base, sugar or internucleotide linkage so as to increase nuclease
20 resistance, stability, specificity or uptake by bacteria of the oligonucleotide.

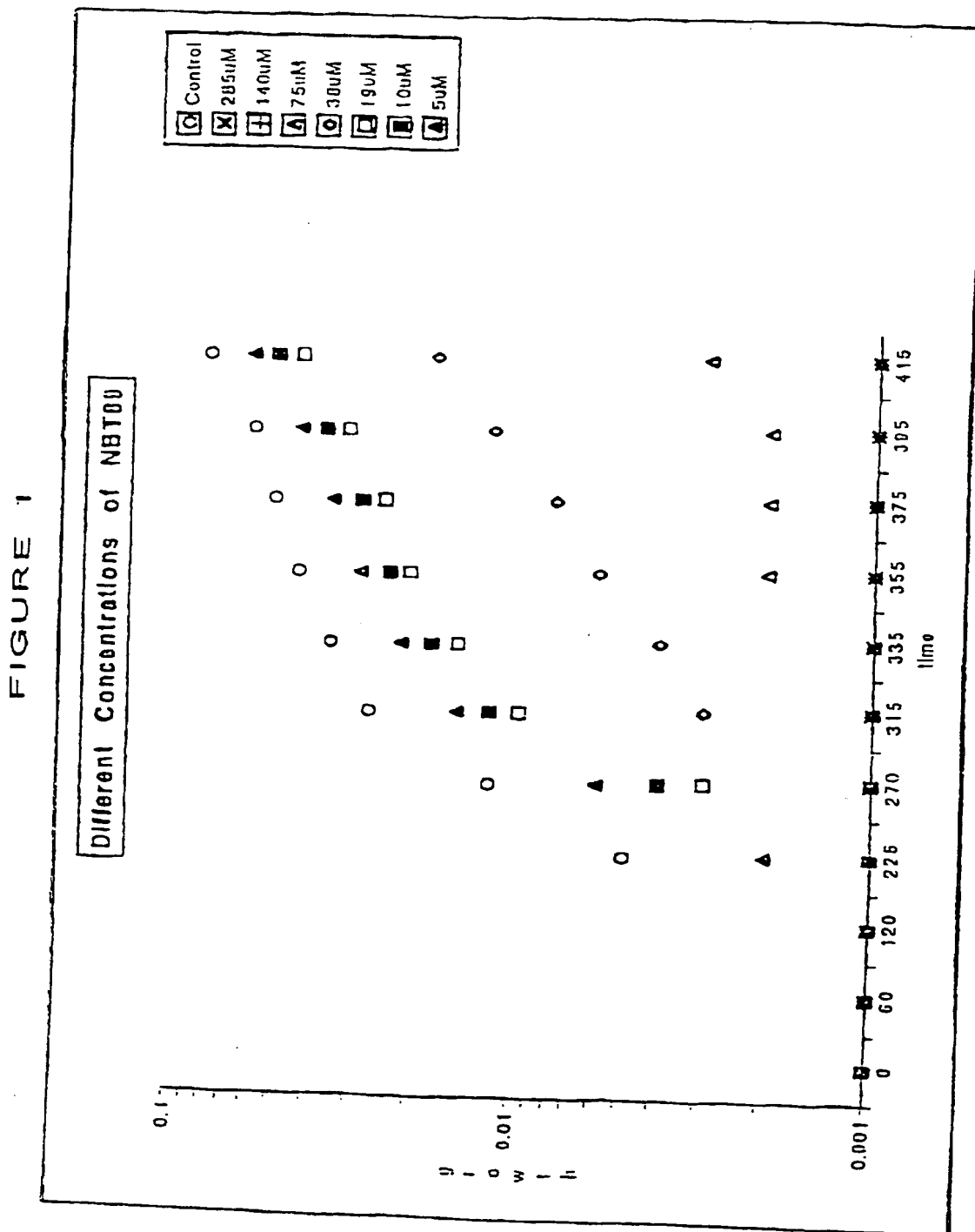
54. The composition of claim 40, wherein the oligonucleotide is selected from at least one of the group consisting of:

- 25 a) partially or fully substituted phosphorothioate oligonucleotides or analogues thereof;
- b) partially or fully substituted alkyl phosphonate oligonucleotides or analogues thereof;
- 30 c) partially or fully substituted phosphate ester oligonucleotides or analogues thereof;
- d) partially or fully substituted phosphoramidate oligonucleotides or analogues thereof;
- e) partially or fully substituted 2' modified RNA oligonucleotides or analogues thereof;
- 35 f) partially or fully substituted morpholino oligonucleotides or analogues thereof;

- g) partially or fully substituted peptide nucleic acid oligonucleotides or analogues thereof;
- h) partially or fully substituted dithioate oligonucleotides or analogues thereof;
- 5 i) partially or fully substituted 5' thio oligonucleotides or analogues thereof;
- j) partially or fully substituted propyne oligonucleotides or analogues thereof;
- k) chimerics of any combination of the above; and
- 10 l) any chemical modifications of the oligonucleotide which leave the oligonucleotide capable of specifically binding the nucleic acid or protein.
55. The composition of claim 40, wherein the bacterium is gram positive.
- 15 56. The composition of claim 40, wherein the bacterium is gram negative.
57. The composition of claim 40, wherein the bacterium is acid fast.
58. The composition of claim 40, wherein the bacterium
- 20 is a member of a genus selected from the group consisting of *Aerococcus*, *Listeria*, *Streptomyces*, *Actinomadura*, *Lactobacillus*, *Eubacterium*, *Arachnia*, *Mycobacterium*, *Peptostreptococcus*, *Staphylococcus*, *Corynebacterium*, *Erysipelothrix*, *Dermatophilus*, *Rhodococcus*, *Bifodobacterium*,
- 25 *Lactobacillus*, *Streptococcus*, *Bacillus*, *Peptococcus*, *Micrococcus*, *Kurthia*, *Nocardia*, *Nocardiopsis*, *Rothia*, *Propionibacterium*, *Actinomyces*, *Enterococcus*, *Pneumococcus*, and *Clostridia*.
59. The composition of claim 40, wherein the bacterium
- 30 is a member of the genus *Staphylococcus*.
60. The composition of claim 40, wherein the bacterium is *Staphylococcus aureus*.
61. The composition of claim 40, wherein the bacterium is a member of the genus *Pseudomonas*.
- 35 62. The composition of claim 40, wherein the bacterium is a member of the genus *Klebsiella*.

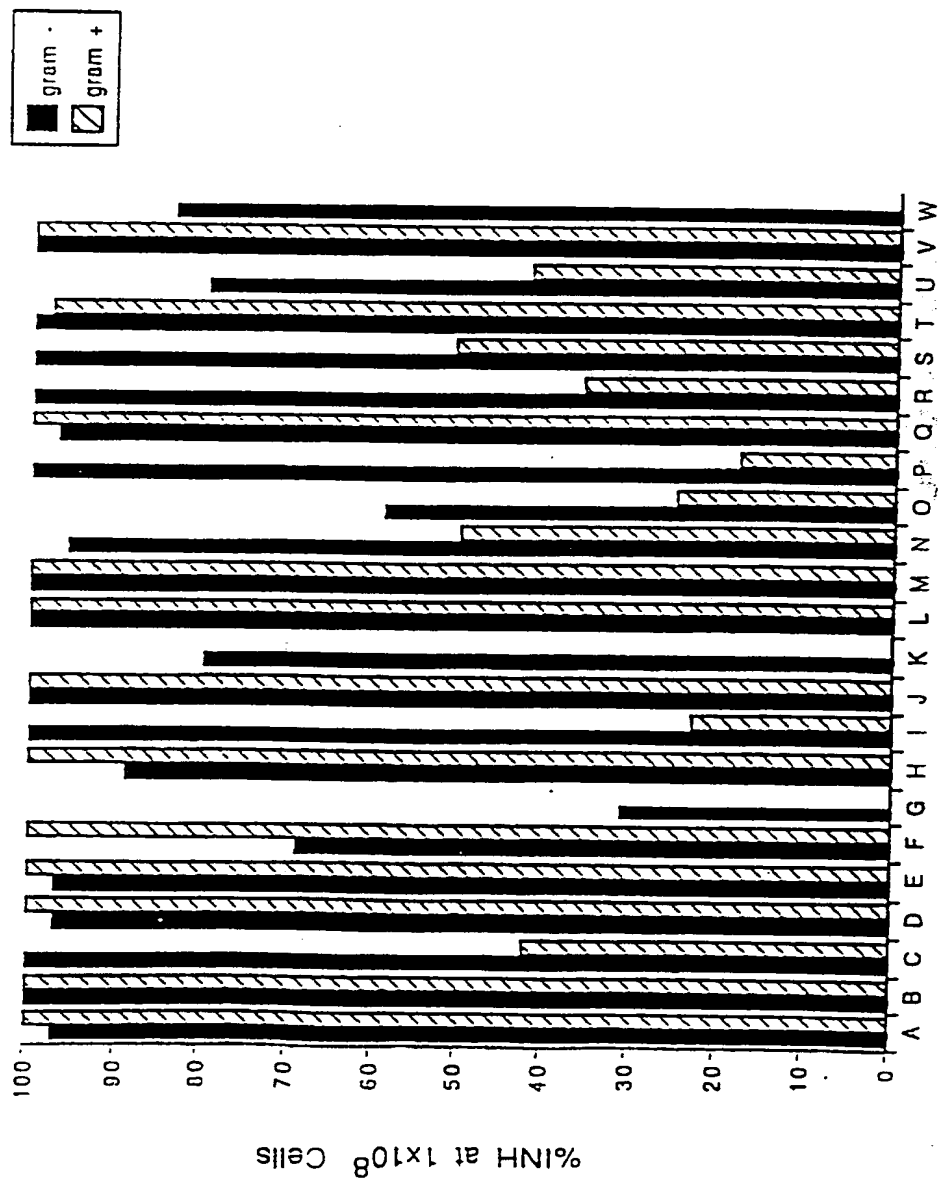
63. The composition of claim 40, wherein the bacterium is a member of the genus *Yersinia*.
64. The composition of claim 40, wherein the bacterium is a member of the genus *Neisseria*.
- 5 65. The composition of claim 40, wherein the bacterium is a member of the genus *Serratia*.
66. The composition of claim 40, wherein the bacterium is a member of the genus *Streptococcus*.
- 10 67. The composition of claim 66, wherein the bacterium is *Streptococcus pyogenes*.
68. The composition of claim 66, wherein the bacterium is *Streptococcus pneumoniae*.
69. The composition of claim 40, wherein the bacterium is a member of the genus *Shigella*.
- 15 70. The composition of claim 40, wherein the bacterium is a member of the genus *Haemophilus*.
71. The composition of claim 40, wherein the bacterium is a member of the genus *Mycobacterium*.
72. The composition of claim 40, wherein the bacterium 20 is a member of the genus *Helicobacter*.
73. The composition of claim 40, wherein the bacterium is a member of the genus *Enterococcus*.
74. The composition of claim 40, wherein the bacterium is a member of the genus *Vibrio*.
- 25 75. The composition of claim 40, wherein the bacterium is a member of the genus *Salmonella*.
76. The composition of claim 40, wherein the bacterium is *Escherichia coli*.
- 30 77. The composition of claim 40, wherein the bacterium is *Pneumococcus*.
78. A compound, comprising:
- a) an antibiotic; and
 - b) a substantially nuclease resistant oligonucleotide having about 8 to about 80 nucleotides and targeted to a 35 nucleic acid or protein in a bacterium, wherein said antibiotic is covalently linked to said oligonucleotide.

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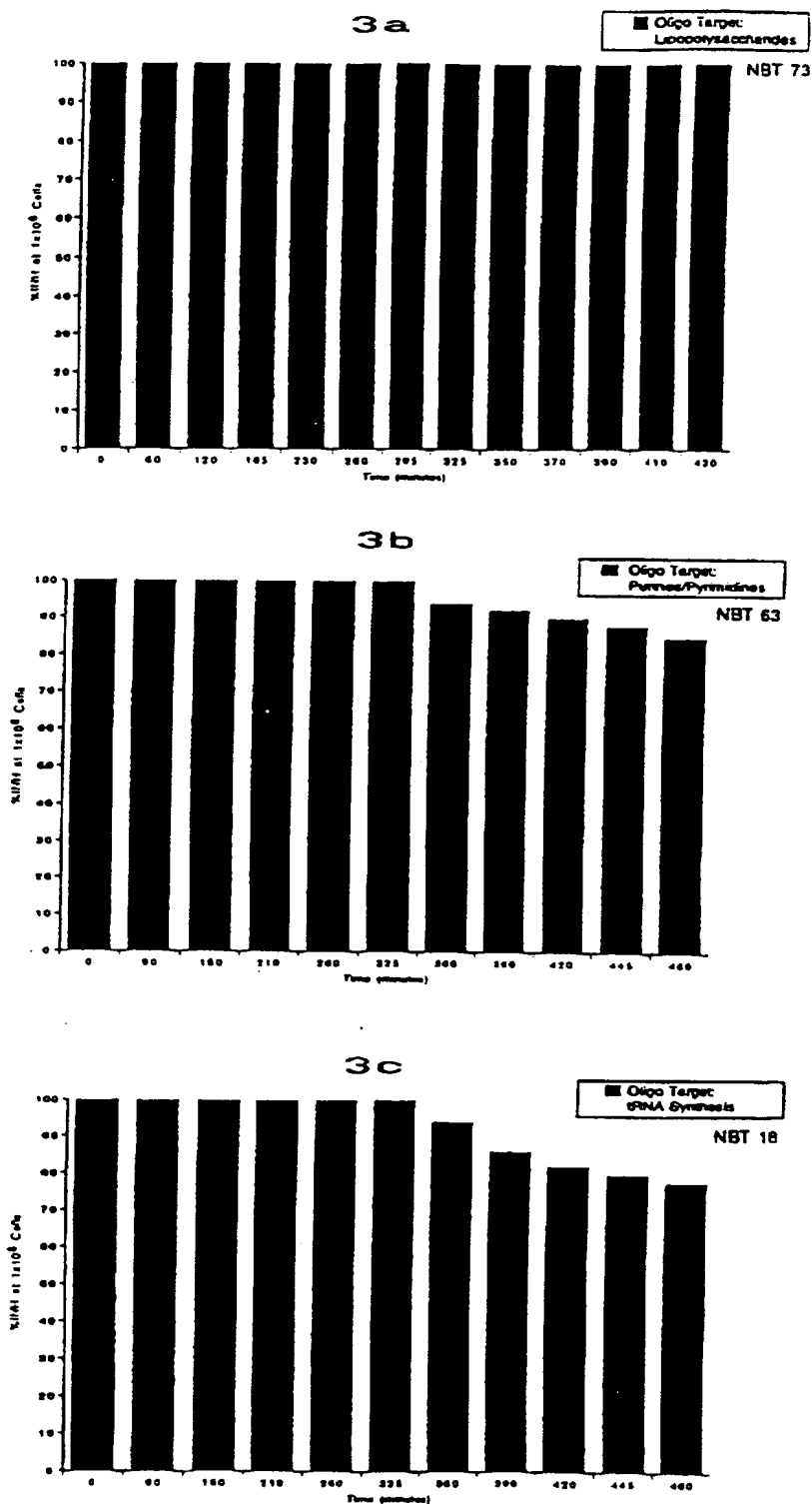
FIGURE 2



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Growth Inhibition of Bacterial Strains with Oligos

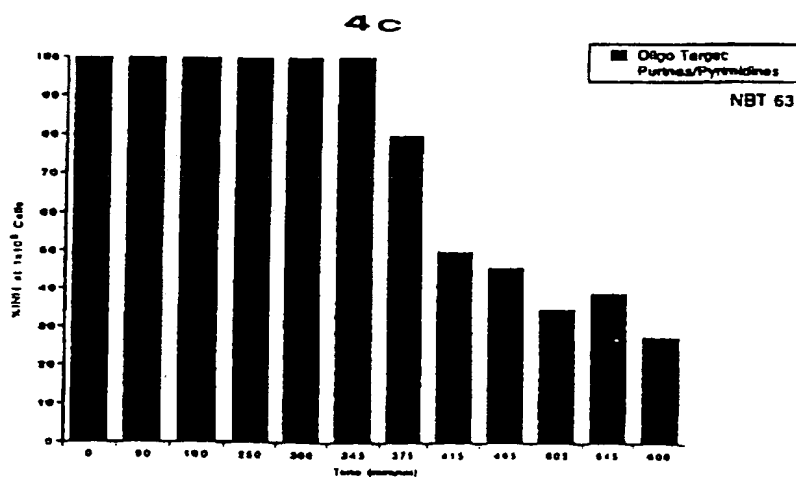
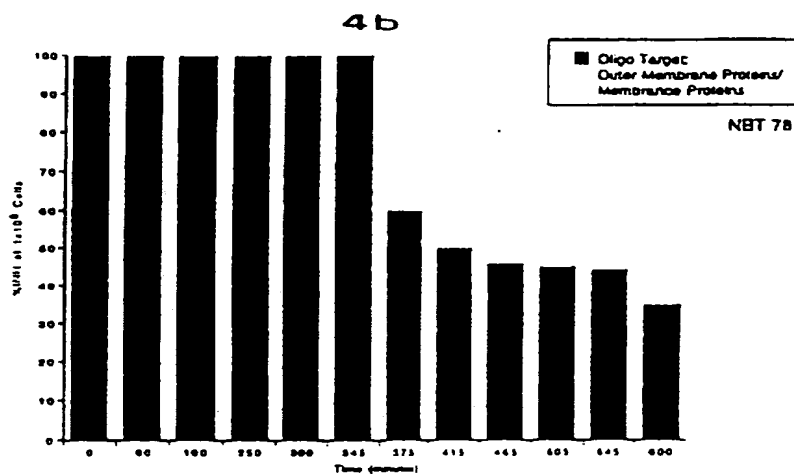
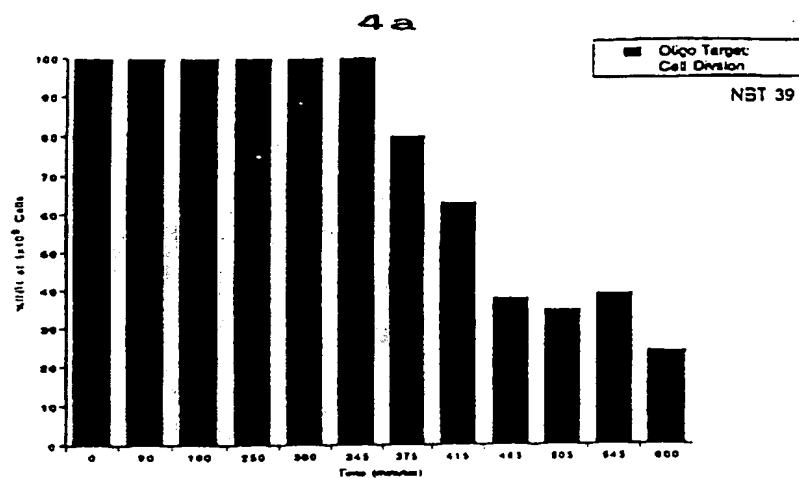
Salmonella



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Growth Inhibition of Bacterial Strains with Oligos

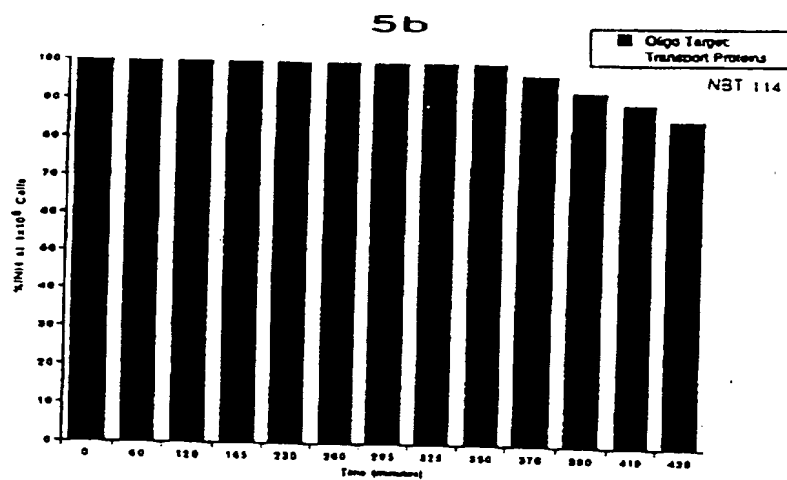
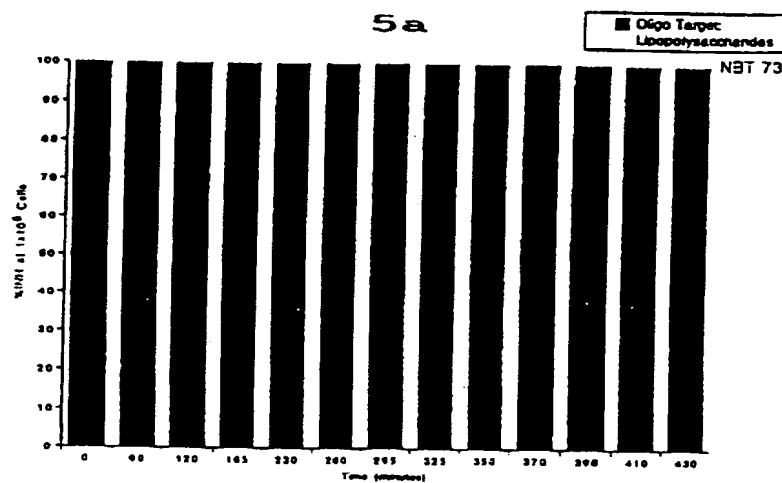
Pseudomonas



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Growth Inhibition of Bacterial Strains with Oligos

Klebsiella

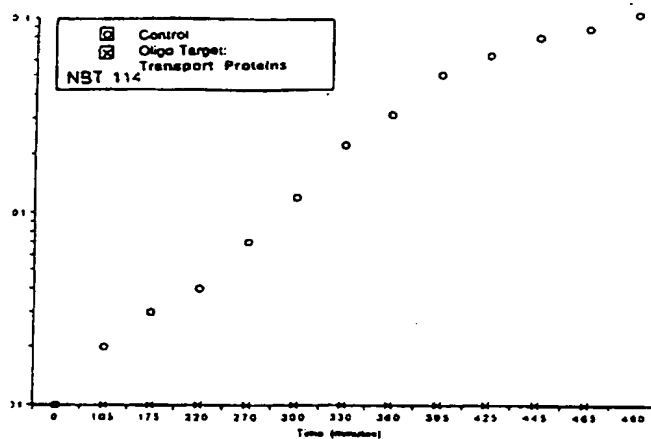


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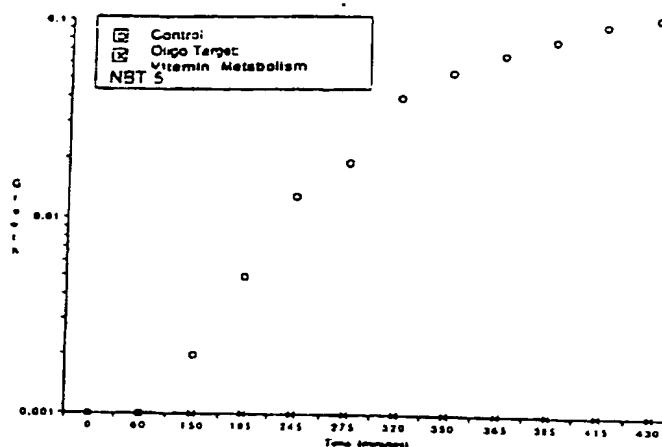
Growth of *E. coli* 35218 (multiple drug resistance) in the Presence of Oligos

6a

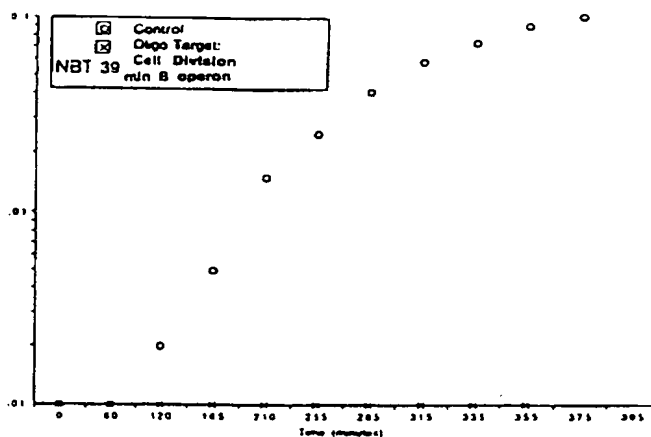
Growth measured at 600 nanometers



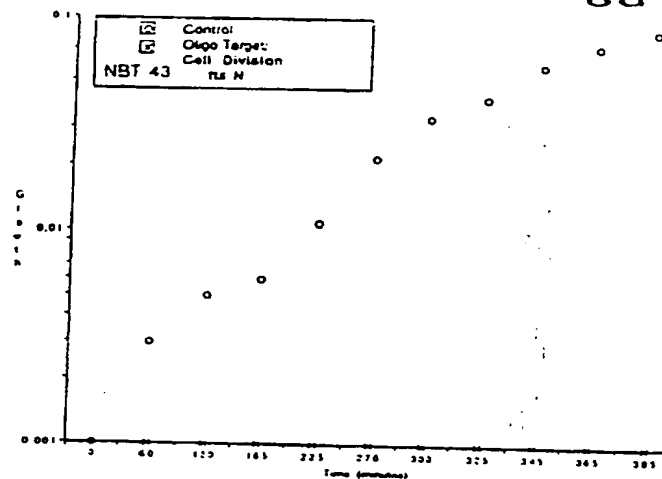
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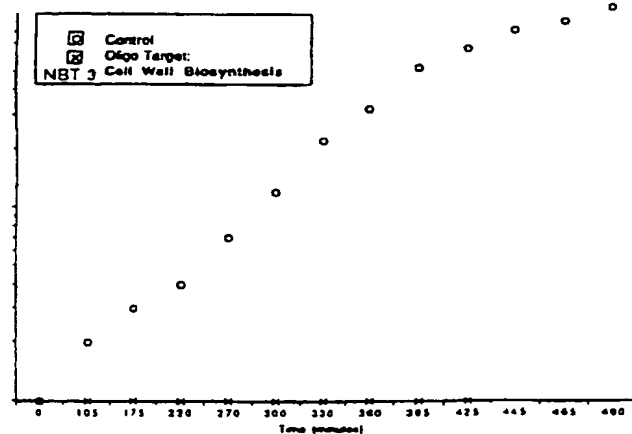
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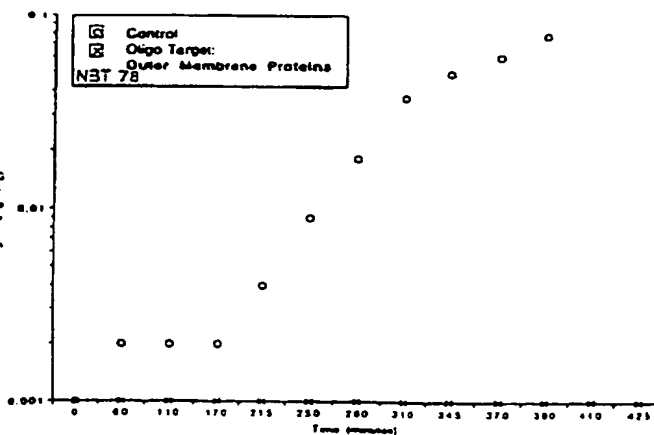
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6e



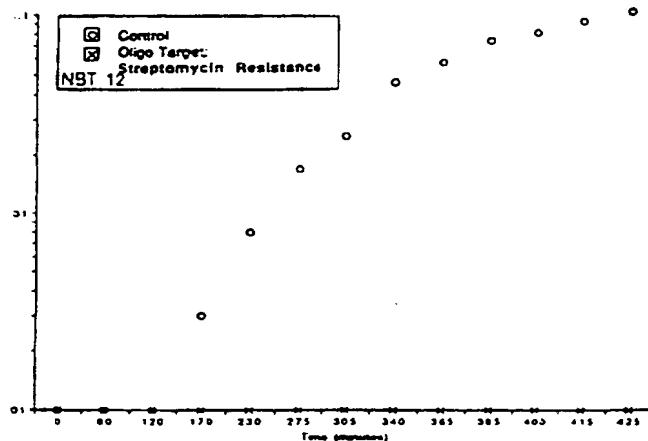
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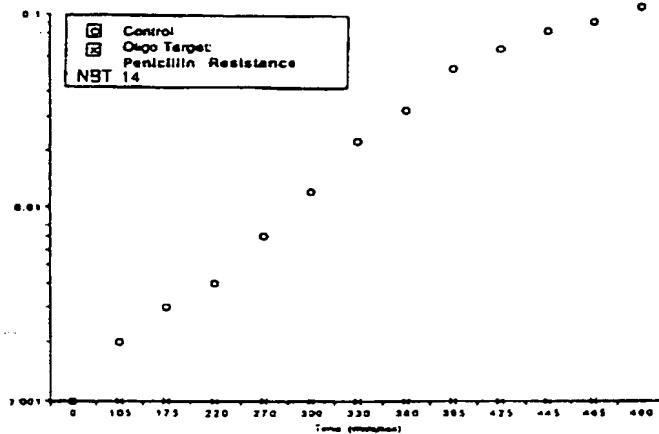
Growth of *E. coli* 35218 (multiple drug resistance) in the Presence of Oligos

6g

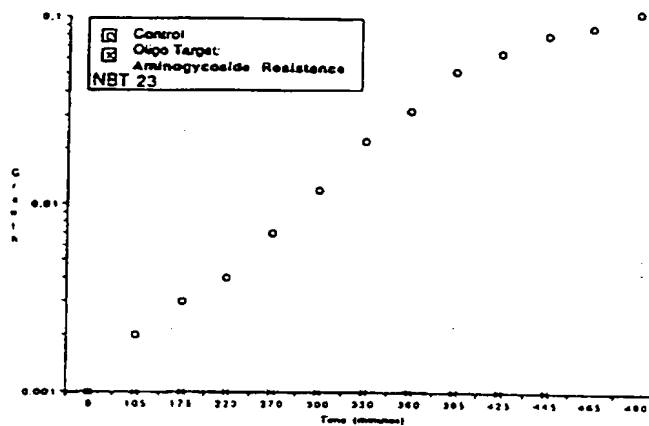
Growth measured at 600 nanometers



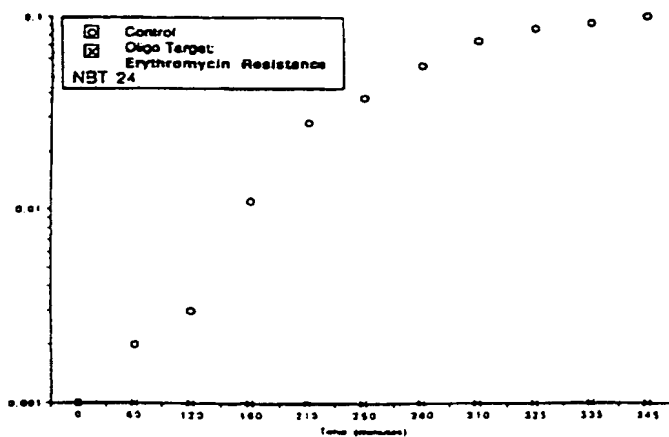
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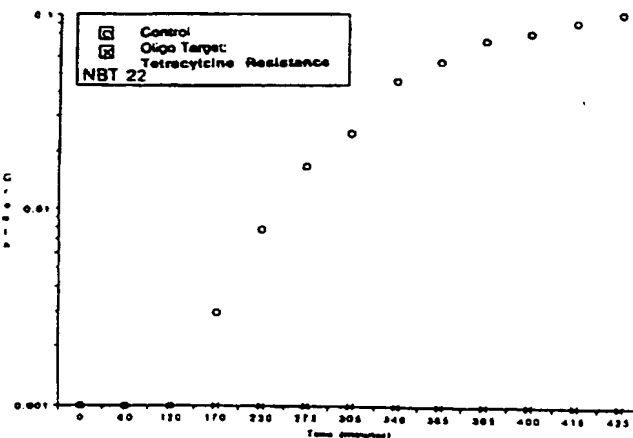
6i



6j



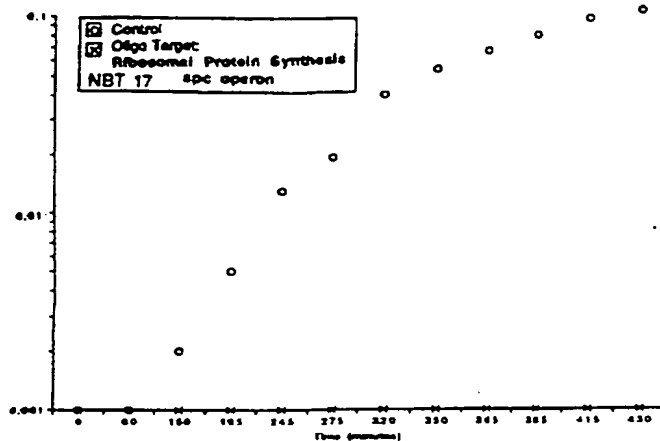
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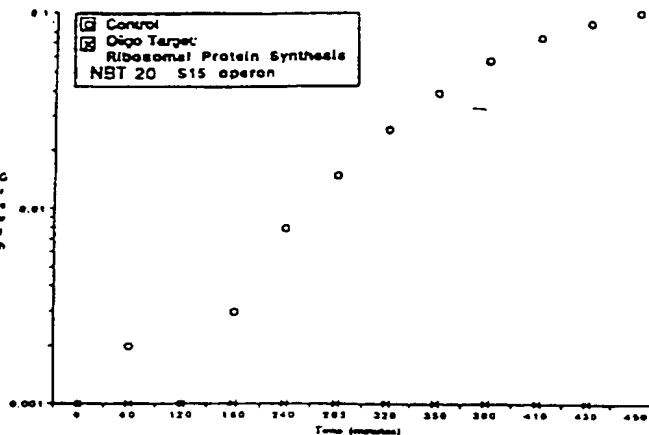
Growth of *E. coli* 35218 (multiple drug resistance) in the Presence of Oligos

6i

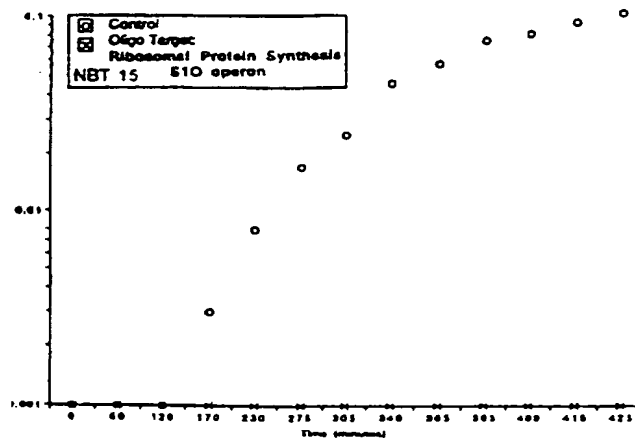
Growth measured at 600 nanometers



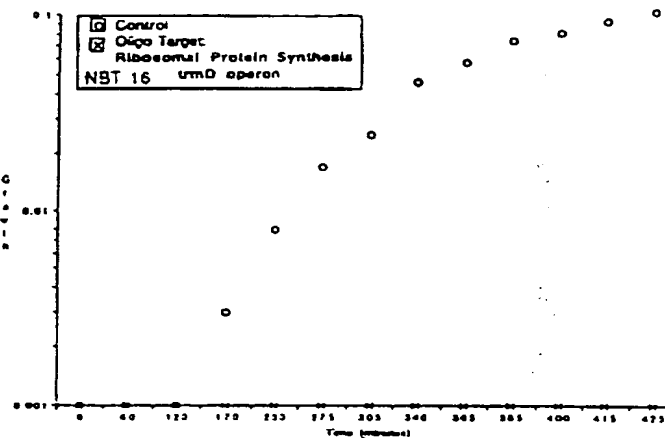
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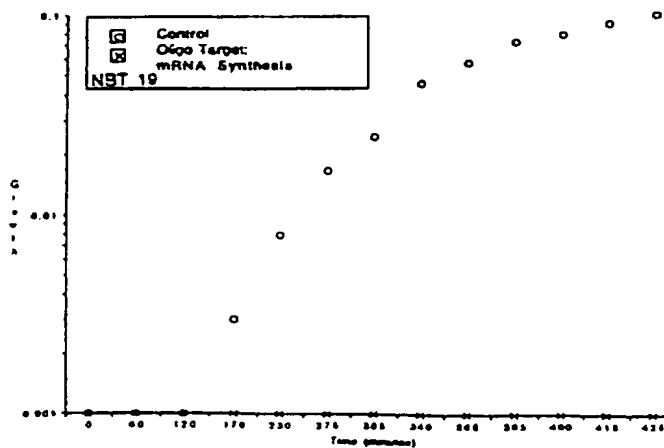
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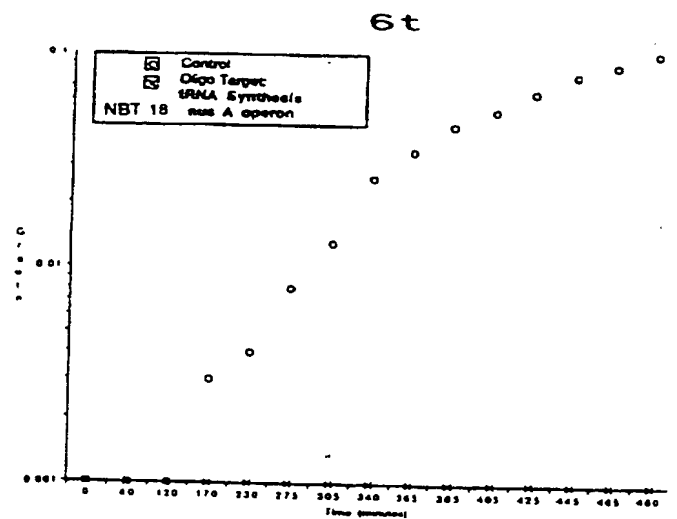
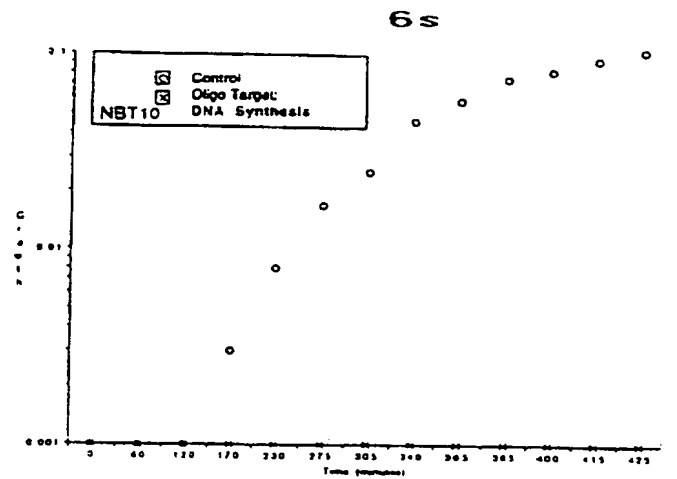
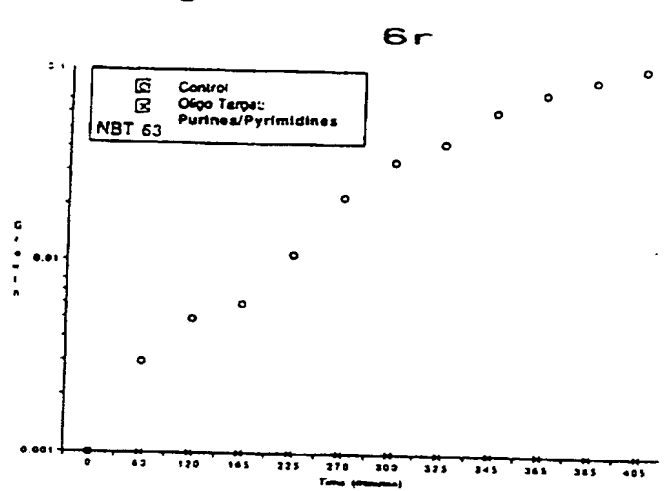
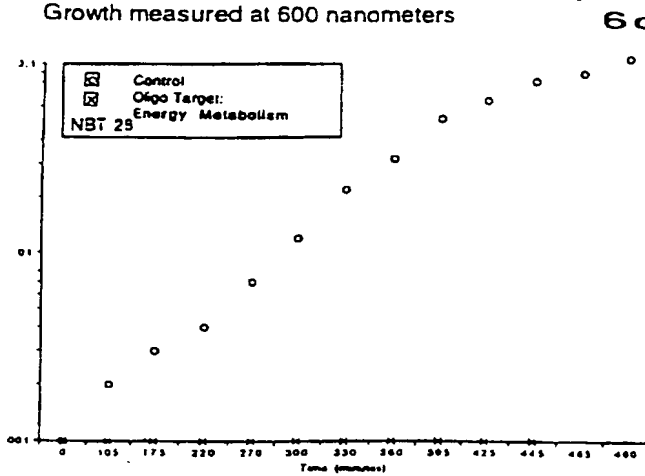


6p



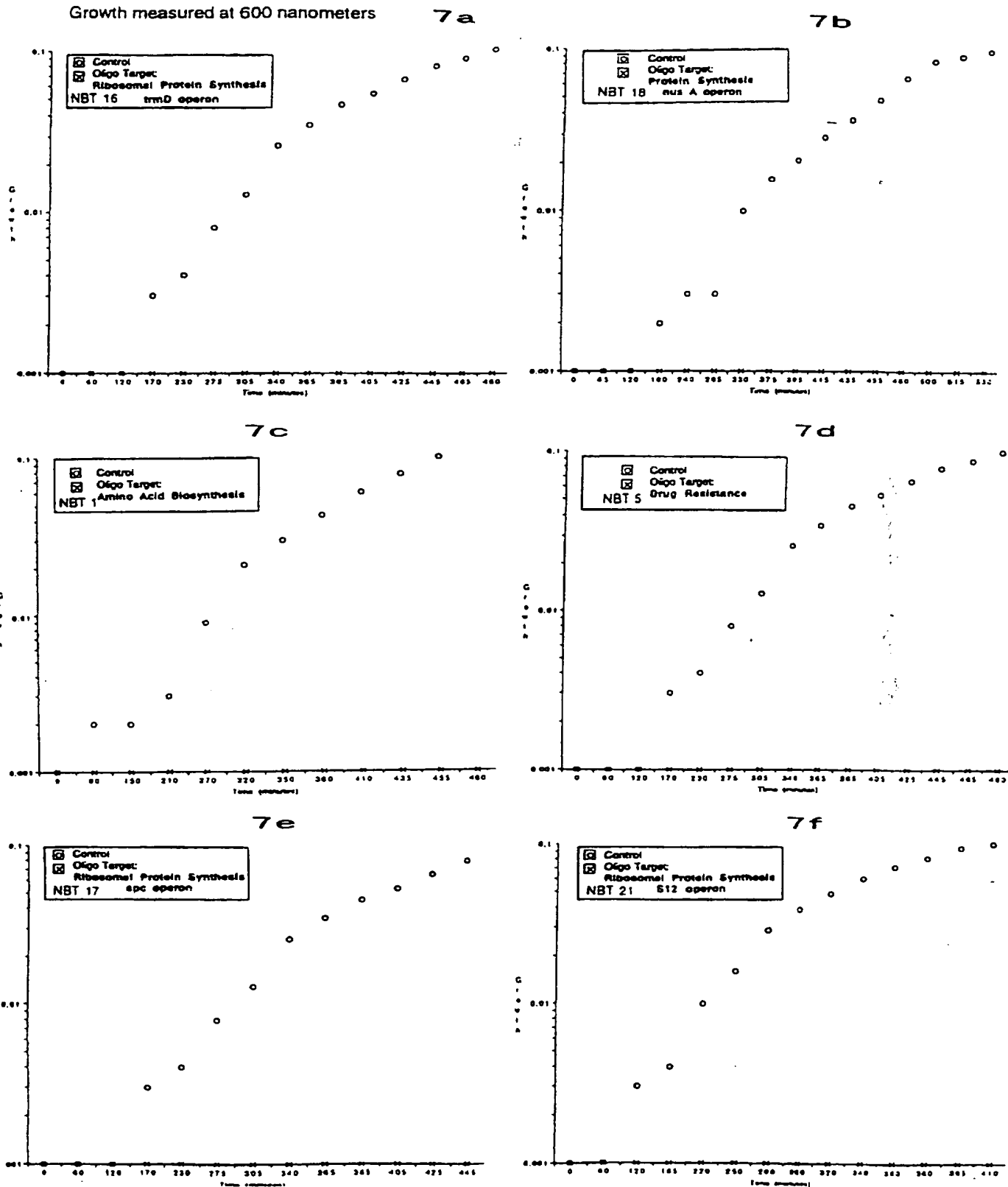
Growth of *E. coli* 35218 (multiple drug resistance) in the Presence of Oligos

Growth measured at 600 nanometers



Growth Inhibition of Staph 13301 (penicillin resistant) in the Presence of Oligos

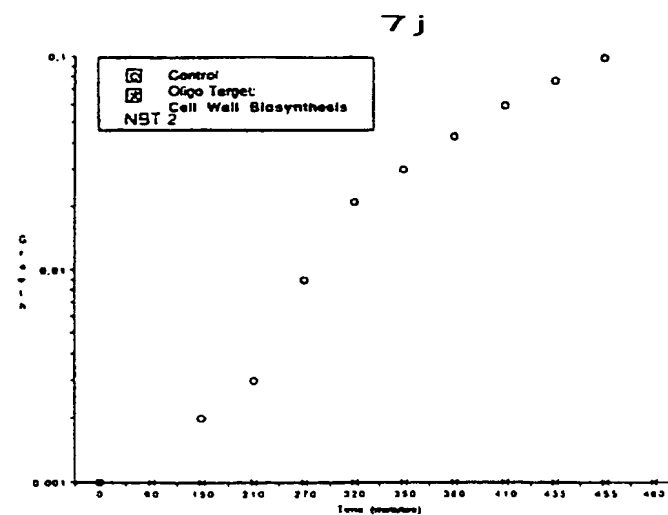
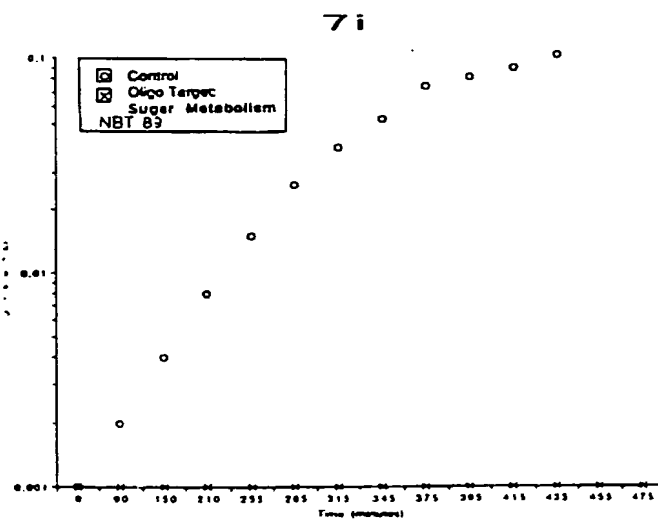
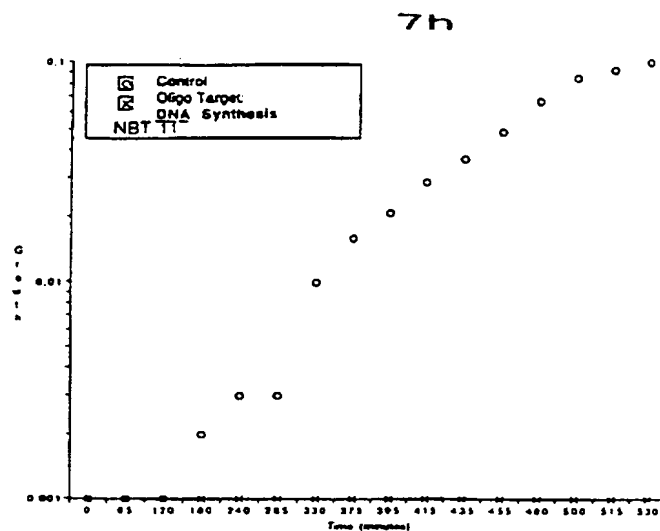
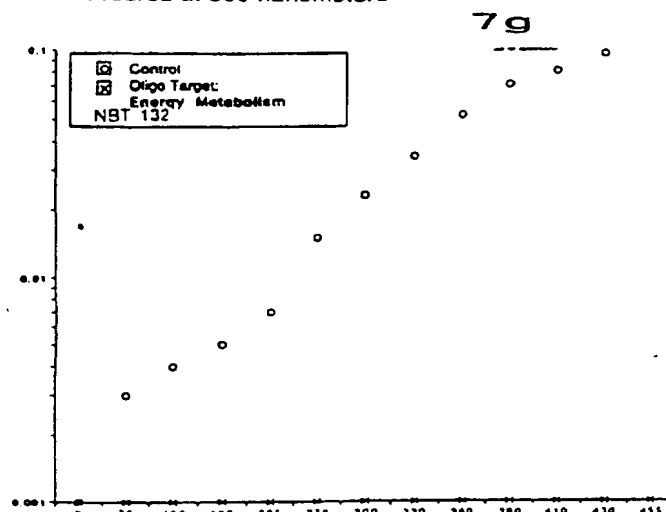
Growth measured at 600 nanometers



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Growth Inhibition of Staph 13301 (penicillin resistant) in the Presence of Oligos

Growth measured at 600 nanometers



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Animal Data

A) Lister Model

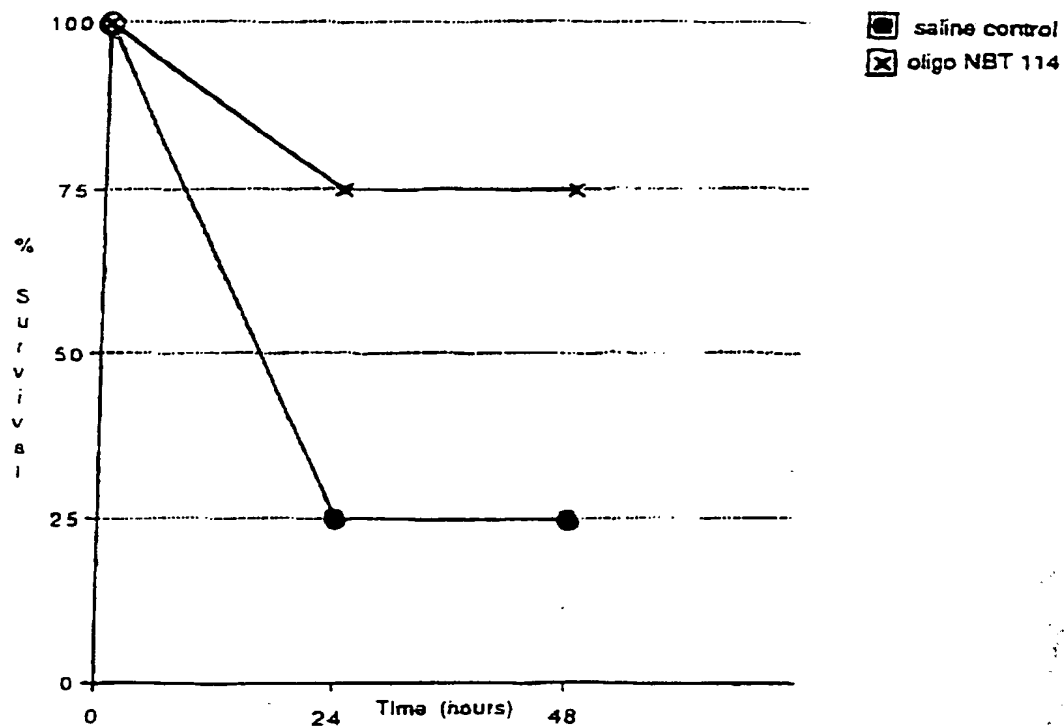


FIGURE 8

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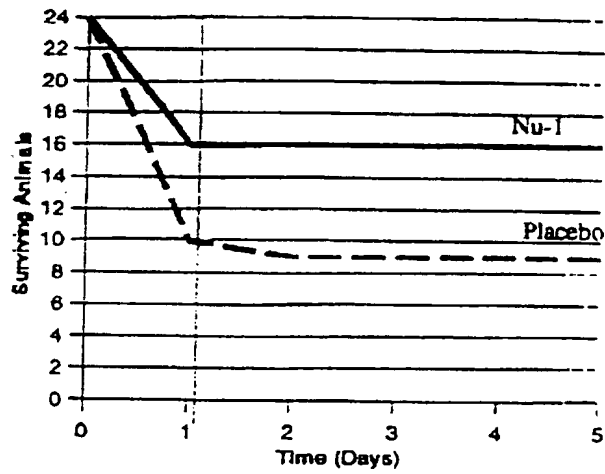
In Vivo Efficacy

FIGURE 9

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Standard Overnight MIC Assay- *Staph. aureus* 3 Day Time Course

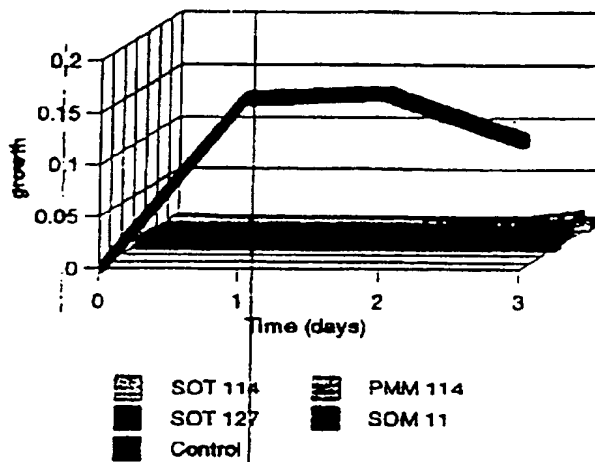


FIGURE 10a

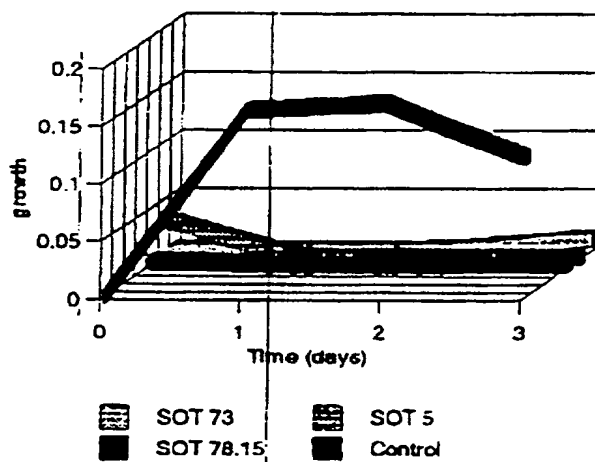


FIGURE 10b

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Standard Overnight MIC Assay *Serratia liquefaciens*

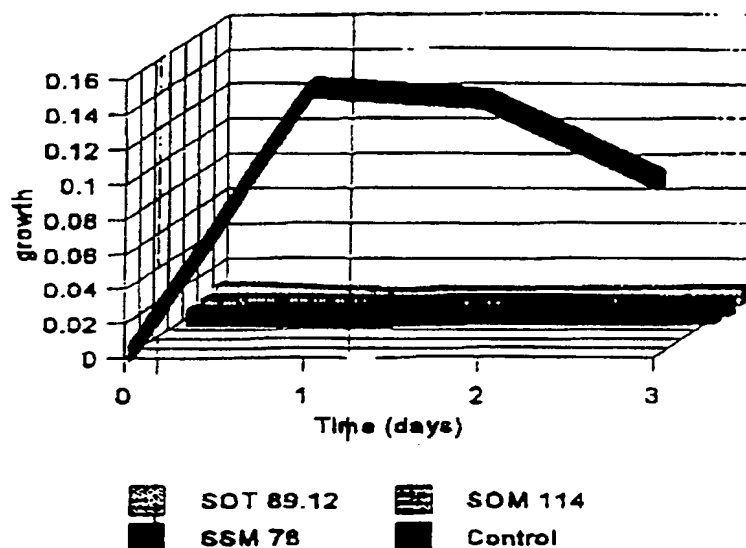


FIGURE 11a

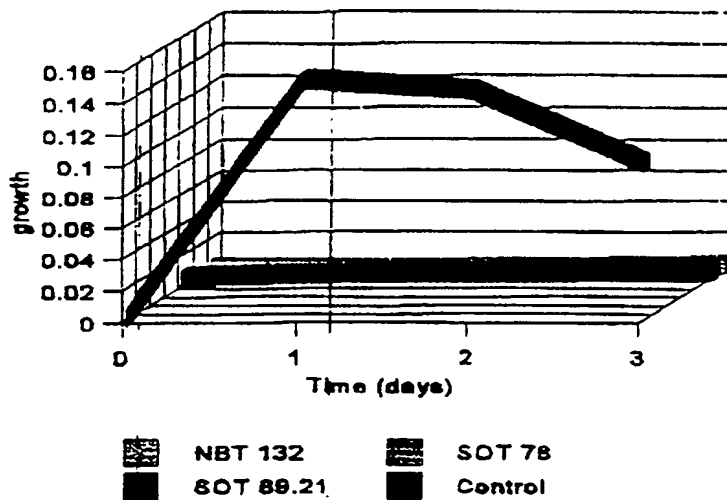
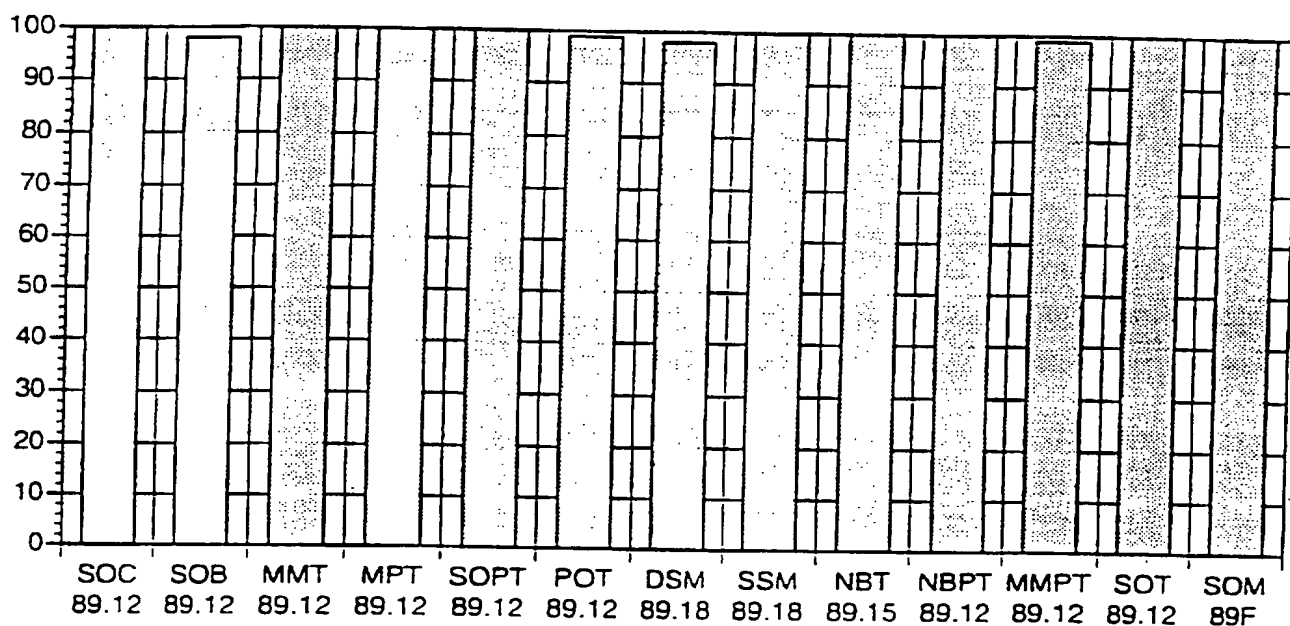


FIGURE 11b

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FIGURE 12

Standard MIC Assay *Staph. aureus*



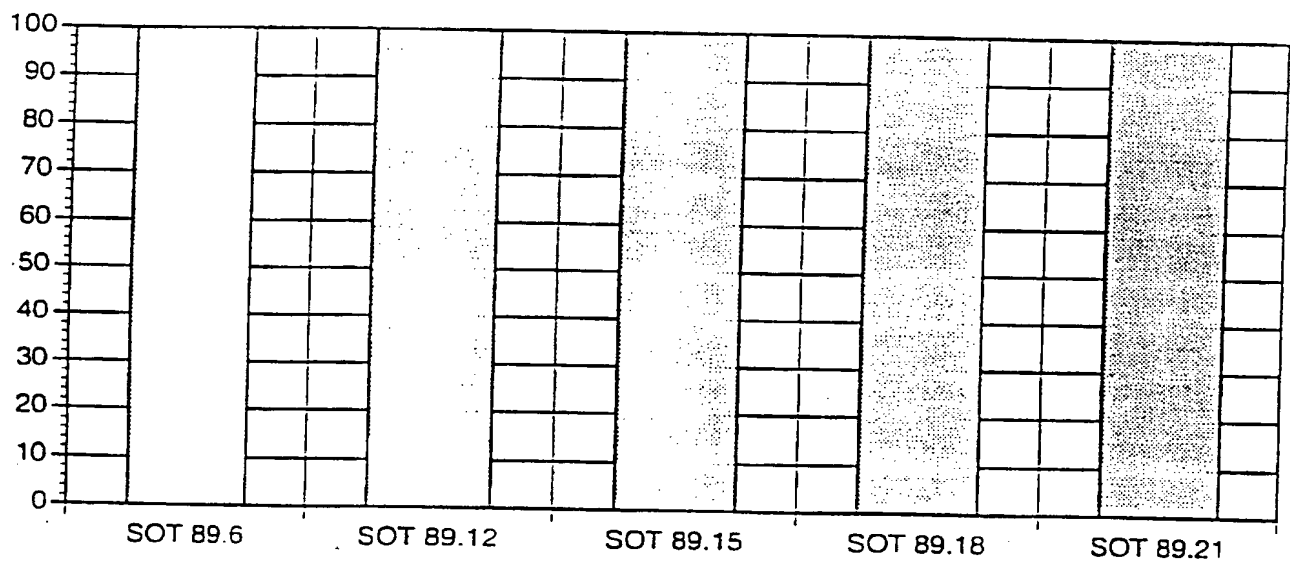
SOC - 5' - 6 Ds 6Mo - Cholesteryl - 3'
SOB - 5' - 6 Ds 6Mo - Biotin - 3'
MMT - 5' - 12 Mo Invert T - 3'
MPT - 5' - 10 Mo 2Mp Invert T - 3'
SOPT - 5' - 6 Ds 4 Mo 2Mp Invert T - 3'
POT - 5' - 12 Po (Invert T) - 3'
DSM - 5' - 8 Ds 10 Ms 1 Do - 3'
SSM - 5' - 18 Ms 1 Do - 3'
NBT - 5' - 14 Ds Do - 3'
NBPT - 5' - 10 Ds 2Mp Invert T - 3'
MMPT - 5' - 10 Mo 2 Mp Invert T - 3'
SOT - 5' - 6 Ds 6Mo Invert T - 3'
SOM-F - 5' - 1 Ms 4Ds 12 Mo 3 Ms 1 Do - 3'

Different constructs that work well in inhibition of bacterial growth.

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FIGURE 13

Standard MIC Assay *Staph. aureus*



SOT 89.6-6mer
SOT 89.12-12 mer
SOT 89.15-15 mer
SOT 89.18-18 mer
SOT 89.21-21 mer

Oligos of different lengths work well in inhibition of bacterial growth.

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Comparison of Oligo 114 and Ampicillin

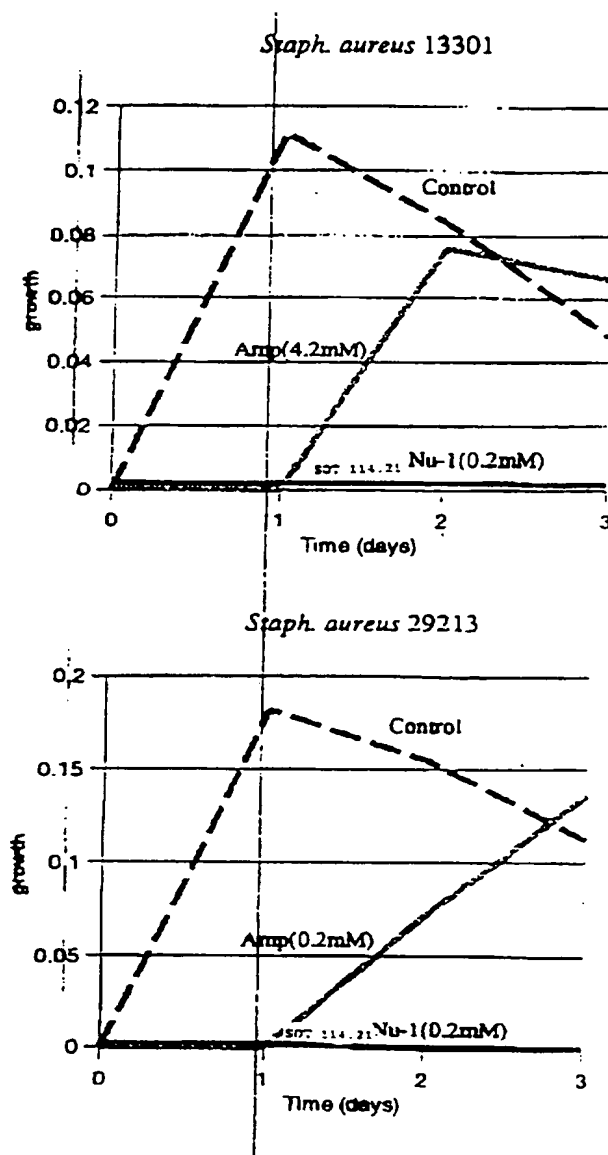


FIGURE 14

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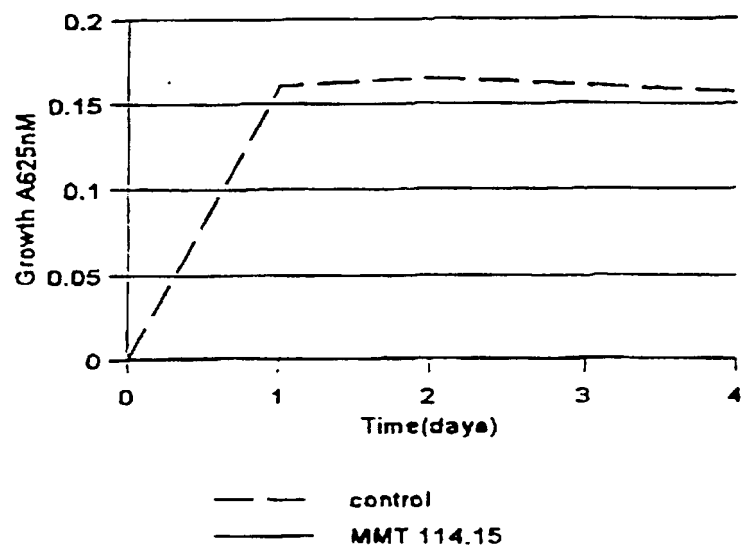
Pseudomonas aeruginosa 10145

FIGURE 15

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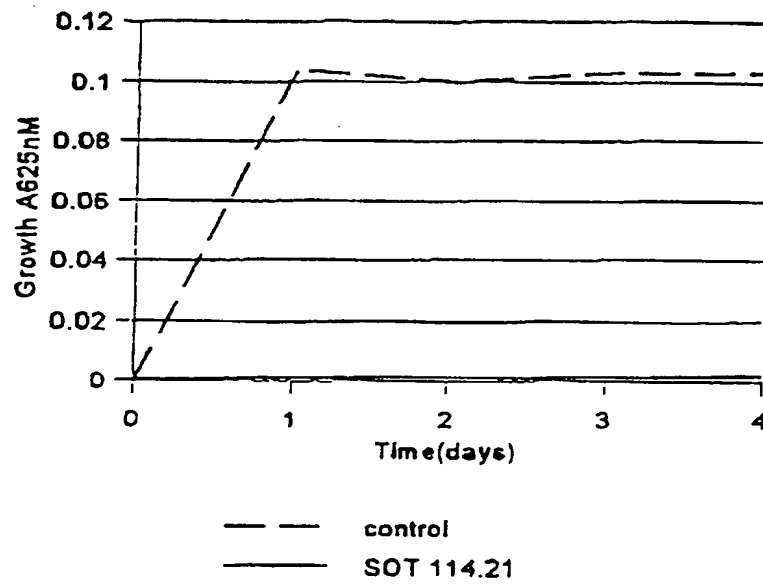
Streptococcus pyogenes 14289

FIGURE 16

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/12961

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C07H21/00 A61K31/70 C12N15/11

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C07H A61K C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|---|-----------------------|
| X | US 5 294 533 A (LUPSKI JAMES R ET AL) 15 March 1994 cited in the application see the whole document --- | 1-77 |
| P,X | WO 96 29399 A (SOD CONSEILS RECH APPLIC ;PIROTZKY EDUARDO (FR); COLOTE SOUDHIR (F) 26 September 1996 see the whole document --- | 1-77 |
| A | L. A. CHRISEY ET AL.: "Internalization of Oligodeoxyribonucleotides by Vibrio parahaemolyticus" ANTISENSE RES. DEV., vol. 3, 1993, pages 367-381, XP002045887 cited in the application --- | |
| | -/-- | |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

6 November 1997

Date of mailing of the international search report

16. 12 97

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|--|---|-----------------------|
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| A | M.A. RAHMAN ET AL.: "Antibacterial Activity and Inhibition of Protein Synthesis in Escherichia coli by Antisense DNA Analogs" ANTISENSE RES. DEV., vol. 1, 1991, pages 319-27, XP002045888 cited in the application --- | |
| A | K. JAYARAMAN ET AL.: "Selective Inhibition of Escherichia coli Protein Synthesis and Growth by Nonionic Oligonucleotides Complementary to the 3' End of 16S rRNA" PROC. NATL. ACAD. SCI. USA, vol. 78, 1981, pages 1537-41, XP002045889 cited in the application ----- | |

INTERNATIONAL SEARCH REPORT

Information on patent family members

Internat. Appl. Application No

PCT/US 97/12961

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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| | | AU 8263491 A | 27-02-92 |
| | | CA 2048450 A | 24-02-92 |
| | | EP 0472434 A | 26-02-92 |
| | | JP 6303977 A | 01-11-94 |
| | | AT 137806 T | 15-05-96 |
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| | | DE 68926455 D | 13-06-96 |
| | | DE 68926455 T | 31-10-96 |
| | | EP 0424473 A | 02-05-91 |
| | | JP 3505672 T | 12-12-91 |
| | | WO 9000624 A | 25-01-90 |
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| WO 9629399 A | 26-09-96 | AU 5149796 A | 08-10-96 |
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| (51) International Patent Classification ⁶ : C07H 21/00, A61K 31/70, C12N 15/11 | | A1 | (11) International Publication Number: WO 98/03533 |
| | | | (43) International Publication Date: 29 January 1998 (29.01.98) |
| (21) International Application Number: PCT/US97/12961 | | | (81) Designated States: AL, AM, AU, AZ, BA, BB, BG, BR, BY, CA, CN, CU, CZ, EE, GE, GH, HU, IL, IS, JP, KG, KP, KR, KZ, LC, LK, LR, LT, LV, MD, MG, MK, MN, MX, NO, NZ, PL, RO, RU, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). |
| (22) International Filing Date: 23 July 1997 (23.07.97) | | | |
| (30) Priority Data: 08/685,575 24 July 1996 (24.07.96) US | | | |
| (71) Applicant: OLIGOS ETC. AND OLIGOS THERAPEUTICS, INC. [US/US]; 29970 S.W. Town Center Loop W., Wilsonville, OR 97070 (US). | | | |
| (72) Inventors: ARROW, Amy; 15 Equestrian Ridge Road, Newton, CT 06470 (US). DALE, Roderic, M., K.; 26761 S.W. 45th Drive, Wilsonville, OR 97070 (US). THOMPSON, Theresa, L.; 2222 S.W. Ek Road, West Linn, OR 97068 (US). | | | |
| (74) Agents: FRIEBEL, Thomas, E. et al.; Pennie & Edmonds LLP, 1155 Avenue of the Americas, New York, NY 10036 (US). | | | Published <i>With international search report.</i> <i>With amended claims.</i> Date of publication of the amended claims: 2 April 1998 (02.04.98) |
| (54) Title: ANTISENSE OLIGONUCLEOTIDES AS ANTIBACTERIAL AGENTS | | | |
| (57) Abstract A novel method is provided that teaches the therapeutic use of nuclease resistant oligonucleotides for treating animals having an infection caused by a pathogenic bacterium. The method involves the integration of (1) methods for selecting the correct oligonucleotide; (2) synthesis and purification of nuclease resistant oligonucleotides, and (3) methods for <i>in vitro</i> analysis of potential antimicrobial oligonucleotides. The described oligonucleotides may comprise modified backbones, sugar residues, bases, or mixtures and have been subject to purification resulting in oligonucleotides that are capable of inhibiting the growth of a broad spectrum of clinically relevant bacterial species. | | | |

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AMENDED CLAIMS

[received by the International Bureau on 12 February 1998 (12.02.98);
original claims 1-78 replaced by new claims 1-21 (2 pages)]

1. The use of a substantially nuclease resistant oligonucleotide having about 8 to about 80 nucleotides in the preparation of a medication for the treatment of infection by pathogenic bacteria.

2. The use of claim 1 wherein said bacteria are gram positive.

3. The use of claim 2 wherein said bacteria is selected from the group consisting of: *Aerococcus*, *Listeria*, *Streptomyces*, *Actinomadura*, *Lactobacillus*, *Eubacterium*, *Arachnia*, *Mycobacterium*, *Peptostreptococcus*, *Corynebacterium*, *Erysipelothrix*, *Dermatophilus*, *Rhodococcus*, *Bifodobacterium*, *Lactobacillus*, *Bacillus*, *Peptococcus*, *Micrococcus*, *Kurthia*, *Nocardia*, *Nocardiopsis*, *Rothia*, *Propionibacterium*, *Actinomyces*, *Pneumococcus*, and *Clostridia*.

4. The use of claim 2, wherein the bacterium is a member of the genus *Staphylococcus*.

5. The use of claim 4, wherein the bacterium is *Staphylococcus aureus*.

6. The use of claim 2, wherein the bacterium is a member of the genus *Streptococcus*.

7. The use of claim 6, wherein the bacterium is *Streptococcus pyogenes*.

8. The use of claim 6, wherein the bacterium is *Streptococcus pneumoniae*.

9. The use of claim 2, wherein the bacterium is a member of the genus *Enterococcus*.

10. The use of claim 1 wherein said bacteria are gram negative.

11. The use of claim 10, wherein the bacterium is a member of the genus *Pseudomonas*.

12. The use of claim 10, wherein the bacterium is a member of the genus *Klebsiella*.

13. The use of claim 10, wherein the bacterium is a member of the genus *Yersinia*.

14. The use of claim 10, wherein the bacterium is a member of the genus *Neisseria*.

15. The use of claim 10, wherein the bacterium is a member of the genus *Serratia*.

16. The use of claim 10, wherein the bacterium is a member of the genus *Shigella*.

17. The use of claim 10, wherein the bacterium is a member of the genus *Haemophilus*.

18. The use of claim 10, wherein the bacterium is a member of the genus *Mycobacterium*.

19. The use of claim 10, wherein the bacterium is a member of the genus *Vibrio*.

20. The use of claim 10, wherein the bacterium is a member of the genus *Salmonella*.

21. The use of claim 10, wherein the bacterium is *Escherichia coli*.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 00/01347

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 C12N15/11 A61K31/70 A61P31/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C12N A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|--|
| X A | <p>WO 98 03533 A (OLIGOS ETC. AND OLIGOS THERAPEUTICS, INC.) 29 January 1998 (1998-01-29)</p> <p>abstract</p> <p>page 8, line 1 -page 17, line 11 page 19, line 1 -page 37, line 9 page 42, line 18 -page 48, line 3 page 51, line 18 -page 57, line 15 page 60, line 9 -page 66, line 29 page 75, line 26 -page 76, line 28 NBT 66 (SEQ ID NO: 22) page 82; table 1 page 132 -page 139; claims 1-78</p> <p>---</p> <p>-/--</p> | <p>1,2, 4-14,27, 28,30, 32,33, 36,37,40 3,15-26, 29,31, 34,35, 38,39</p> |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

19 June 2001

Date of mailing of the international search report

17. 9. 01

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|---|-----------------------|
| A | US 5 945 290 A (COWSERT, L.M.) 31 August 1999 (1999-08-31) the whole document | 1-40 |
| A | HEMMINGSEN, S.M. ET AL.: "Homologous plant and bacterial proteins chaperone oligomeric protein assembly" NATURE, vol. 333, no. 6171, 26 May 1988 (1988-05-26), pages 330-334, XP002114158 cited in the application see especially: page 331; figure 1 page 334, column 1, line 31 -column 2, line 10 the whole document | 1-40 |
| A | IVIC, A. ET AL.: "Deletion of Escherichia coli groEL is complemented by a Rhizobium leguminosarum groEL homologue at 37 C but not at 43 C" GENE, vol. 194, no. 1, 18 July 1997 (1997-07-18), pages 1-8, XP004084653 cited in the application the whole document | 1-40 |

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Information on patent family members

International Application No

PCT/CA 00/01347

| Patent document cited in search report | | Publication date | Patent family member(s) | Publication date |
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| | | | WO 0017223 A | 30-03-2000 |

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